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**A QUARTERLY ECONOMETRIC MODEL
OF THE U. S. LIVESTOCK SECTOR**

BY

MARY ANNE VIANA~ BENNETT

**A thesis submitted
in partial fulfillment of the requirement for the
degree Master of Science
Major in Economics
South Dakota State University
1985**

ACCOMPLISHMENT

**A QUARTERLY ECONOMETRIC MODEL
OF THE U. S. LIVESTOCK SECTOR**

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Wayne D. Ellingson
Thesis Advisor

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Date

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This thesis is dedicated to the memory of my father, Emilio Fernandes Viaña. He was a man who valued justice, freedom, and the worth of the individual. He endeavored to teach me to value myself not only for who I was but for the person I could become. He sowed kindness and reaped love and affection from many. This one's for you, Dad, with my love and respect.

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INTRODUCTION

The livestock sector is one of the most important sectors in the economy of South Dakota, accounting for between 50 and 70 per cent of total agricultural cash receipts. In 1981, livestock cash marketings were \$1,865,430 of total marketings of \$2,789,319. Nationally, about half the cash marketing receipts (\$69.2 billion of the total of \$138.7) came from marketing of livestock and products (27).

Given the importance of the livestock sector to both the United States and South Dakota economies, it is vital to have the best and most accurate information available for planning by both livestock producers and government agencies.

Economic Problems of the Livestock Industry

In the next few sections, some of the more important economic problems faced by the livestock industry will be discussed. The first is due to the biological nature of livestock production. The others have to do with the effect of government policy decisions and world market conditions on the domestic livestock industry.

Biological Nature of Livestock Production

Due to the biological nature of the livestock industry there are substantial time lags between the decision to produce and the realization of that decision. For example, at least three years are needed to increase beef production and at least one to change hog production. While it is possible to slaughter breeding stock and increase, in the very short run, the supplies of these meats, changes in supplies of livestock products essentially are limited in the long run by availability of female stock and the time required to produce a new generation (25). This is in contrast to most other production where the decision to increase output involves a much shorter time lag.

A cow-calf operator could have a lag of approximately 15 to 17 months between the time when a decision is made to produce a calf to when that calf is ready to be sold. The feedlot operator faces a similar situation due to the length of time between the placing of a steer or heifer on feed and the realization of the final product of that operation, a slaughter animal.

Pork and poultry producers have similar situations involving time lags. For example, pork producers running

farrow to finish operations have a four month period between breeding and farrowing followed by a four to six month feeding period. Those engaged in feeder pig production or hog finishing alone still face a lag between the time production begins and the realization of the end product, either feeder pigs ready to be sold to feed lot operators or slaughter hogs. To substantially increase poultry production takes approximately nine months. From the time a chick is placed in the hatchery supply flock it takes 176 days to obtain more eggs, 24 days to hatch those eggs, and 52-56 days to produce, slaughter, and ship the broilers.

Due to these lags between production decisions and their realization, livestock producers, and indeed all agricultural producers, are in the unfortunate position of making their production decisions on the basis of prices which might or might not be at the same level as when the decision is realized. This forces the livestock producer to rely on forecasted or predicted prices rather than actual prices when they are making production or marketing decisions.

Other Factors

Of the other factors that have economic impact on livestock producers, and the livestock industry as a whole,

two of the more important ones are government policy decisions and general world market conditions.

Domestic Policy The recent dairy program designed to reduce milk production is an example of how domestic policy decisions impact the livestock industry. The 1983 Dairy and Tobacco Adjustment Act resulted in a program to pay dairy farmers not to market milk; program participants received a direct payment of \$10 per hundredweight for the amount of the reduction. One effect of this reduction in milk production was an increase in the number of cows culled from dairy herds. In South Dakota alone, there was an estimated increase of 7,356 in the number of cows culled above the normal cull rate of 10,755. In the United States, there was an increase of 339,232 in planned cull cow slaughter over the normal 552,493 (34). No attempt to analyze the specific impact on beef supply will be made here beyond a simple noting of the basic economic reality that an increase in the supply of a commodity will, ceteris paribus, result in a lower price received by the supplier.

Another example of policy decisions affecting livestock producers is the 1973 price controls imposed by the federal administration. Since, in the long run, farm prices must equal retail price minus all charges for

world are as follows.

transporting, processing, storing, wholesaling, and retailing, as well as profit, downward pressure on retail prices will cause farm prices to move in that same direction (49).

World Market Conditions For many agricultural commodities, a world view is essential to understanding why prices change. Tomek and Robinson (25) propose that grain prices in the United States are strongly influenced by what happens to production in Canada, Argentina, Australia, and increasingly, the Soviet Union. Therefore, an understanding of conditions in these countries is necessary to adequately explain and forecast prices for United States feed and food grains. Cromarty and Myers (9) stated that no other single factor has had a greater impact on United States commodity prices than the world supply and demand for food and feed grains. Accordingly, the world food crises of the 1970's caused by poor harvests, droughts, etc. had a definite impact on livestock prices through their effect on grain prices.

Implications

The implications of the fact that the United States livestock industry is seriously affected by government policy decisions and events occurring in the rest of the world are as follows.

1. Government decision makers need to know or be able to estimate the impact of their policy decisions.
2. Forecasters need to be able to quantify the effects of policy instruments.

One tool that has been used to forecast prices as well as to measure the expected impacts of policy decisions is econometric modeling. Crom (8) developed a price-output model of the United States beef and pork sectors that could be used to project livestock price and output values in future periods, examine the effects of either government or private policy changes on the beef and pork sectors, and trace out the effects of structural changes in these livestock sectors. For example, government policy changes could be introduced into the model by changing exogenous corn price (indicating a change in government support price for corn), and the effect on beef and pork prices and quantities of these two meats supplied could be measured. A study of the effects of United States government policies with respect to importing of beef on domestic beef production and prices was the basis for the construction of an econometric model describing production, consumption, and importation of beef in the United States by Hunt (19). By

manipulation of the quota variable in the import demand equation of that model, one could simulate conditions of free trade or autarky (no trade). Arzac and Wilkinson's econometric model of the United States livestock and feed grain sectors (1) can be used to provide quarterly forecasts for such variables as livestock and grain prices and production, retail-producer price spreads for meat products, and consumer demand for meat.

Econometric Modeling of the Livestock Sector

Econometric models have been used to forecast and simulate effects of various policy decisions. Specific examples of econometric models of the livestock sector will be discussed in the ensuing chapters; here a brief examination of the role of econometrics and econometric modeling in an analysis of the livestock industry will be made.

According to Blakeslee (4), the objective of the modeling process is to produce a structure, quantitative in character, which may be regarded as an approximate analog to the system which determines the values of variables in the market under study. An economic model of the livestock industry is an attempt to characterize the structure of that system. An econometric model involves an empirical

estimation or measurement of those economic relationships identified by the economic model. The result would be a quantification of the operating characteristics of the market, in this case the livestock market in the United States.

There are three principal uses of econometric models. The first is for structural analysis, which involves use of an estimated econometric model for the quantitative measurement of economic relationships. A second use of econometric models is to forecast or predict quantitative values of certain variables outside the sample of data actually observed. The third use of econometric models is for policy evaluation by quantifying the likely impacts of alternative policies.

According to Jacob Marschak (23), knowledge is useful if it helps to make the best decisions. Econometric models have been used in dealing with the economic problems of the livestock sector mentioned earlier, namely, production and policy analysis decisions.

Basis for the Study

In the past 25 years, several econometric models have been developed in the area of livestock and feed grain production and marketing. A description of several of these models will be presented in the next chapter.

One objective of the project upon which this thesis is based is the development of a quarterly econometric model of the United States livestock sector. Since there are already several econometric models of the livestock industry, it would be appropriate here to list some justifications for development of another.

One justification for development of another model is that there has been an apparent change in the structure of the livestock industry since the early 1970's, which is when most models were developed. For example, according to Ball and Chambers (3), the livestock industry of the 1980's is more concentrated and highly specialized than that of the 1960's or 1970's. The OPEC oil embargo and poor worldwide harvests in the early 1970's also contributed to the economic changes which resulted in very different price relationships in the livestock industry. For example, the oil embargo resulted in higher input costs to grain growers; these increased costs were passed on to livestock producers in the form of higher feed prices. The increased demand for imports of grain by other countries as a result of the poor harvests served to shift out the aggregate demand curve for United States feed grains which, in turn, resulted in increased domestic prices for these commodities. Again,

livestock producers were forced to pay higher prices for grain to feed their livestock.

Other justification for the development of another econometric model is provided by the fact that each of the econometric models discussed in this thesis, although appropriate in the time periods during which they were developed, lacks something necessary to completely explain and analyze the livestock industry of today. For example, there currently is no up-to-date quarterly model of the United States livestock sector which includes equations explaining the behavior and structure of the beef cattle, hog, and broiler markets and their primary feed grain, corn.

Freebairn and Rausser (15) include all the above livestock categories in their model but use an annual basis. Arzac and Wilkinson (1) have a quarterly econometric model of the United States livestock industry which does include beef cattle, hogs, broilers and feedgrains but their model was estimated using data only through 1975. They also do not use a per capita basis for their consumer demand equations which is at variance with the usual practice (12).

Objectives

In recent years, there has been a renewed interest in agricultural commodity price analysis and price

forecasting. With the large increases in prices experienced during the 1970's, the traditional forecasting models were sometimes found to be inadequate (20). This has caused agricultural economists to re-evaluate present forecasting tools and search for possible improved methods.

Objectives for this Study

The first objective of this study is to develop a quarterly econometric model of the major livestock enterprises in the United States. The livestock enterprises to be included in the model are feeder and slaughter cattle, hogs, and poultry. Quarterly data will be used in the model whenever possible. One reason for this is that some researchers have contended that equations based on quarterly data seem to have a much greater chance of reflecting adjustments in the various meat industries than do annual models (2). Crom explained his use of quarterly data in his model for the beef and pork sectors as being due to the fact that the quarter represents a more refined detailed description of temporal economic activity, while being long enough to be free from fluctuations due to very short-run random events (8). Another consideration in selection of

time periods to be used in the model is the biological cycle of the livestock to be included.

A second objective is to simulate the model over the historical period of the study (1960 - 1981) and compare the predicted values for the endogenous variables with the actual values.

A third objective is to conduct analysis of the effects of policy decisions on the livestock sector. For example, one section of the 1985 Farm Bill proposes a gradual (over a four year period) lowering of support prices for wheat and other feed grains to approximately 75 per cent of average domestic price. In this study, the immediate and long-term effects of this policy change in the government's farm program will be presented and discussed. The fourth and final major objective of this study is to provide a needed component (an econometric model of the livestock sector) for a larger composite price forecasting project of which this study is a part.

Hildreth and Jarrett

In 1955, Hildreth and Jarrett (18) published a statistical study of livestock production and marketing. Their major objective for the study was to obtain quantitative approximations to some of the underlying

LITERATURE REVIEW

There has been a great deal of research done in the past in the area of agricultural economics dealing with price forecasting models. For the most part, those works selected for inclusion in this chapter are those which have come to be considered very important to the development of econometric modeling of the livestock sector. Other works are included because of their usefulness as building blocks for different sections of the model developed in this project.

Early Econometric Livestock Market Models

Those works which were put into the category of early econometric models were not that distant chronologically from the later models, but differ mainly in level of sophistication of techniques and amount of aggregation.

Hildreth and Jarrett

In 1955, Hildreth and Jarrett (18) published a statistical study of livestock production and marketing. Their major objective for the study was to obtain quantitative approximations to some of the underlying

relations determining quantity and price of livestock products produced and sold in the United States each year.

They converted price and quantity data for various livestock products into aggregate indices relating to prices received by farmers and quantities sold by farmers to dealers or processors or consumed on farms. Individual livestock products included in the livestock products aggregates were cattle, calves, hogs, chickens, turkeys, sheep, milk, and eggs. Their final model, which went through three major revisions, included relations for livestock production, demand for and supply of feed grain, demand for and supply of protein feed, demand for and supply of livestock products, and an inventory relation. They estimated a model which was based on annual data for the period 1920-1949 using both limited information and least squares methods.

Fox

In the first of two studies by Fox to be reviewed in this chapter, he (13) used annual data to estimate demand functions for livestock products for the period 1922 through 1941. Livestock products included in the study were pork and hogs, beef and cattle, mutton and lamb, veal and calves, poultry and eggs, and dairy products. Fox also included an aggregate measure of meat and meat animals.

Virtually all quantity and income variables used in the relations were placed on a per capita basis. The series were converted to logarithms and the regression equations were fitted to first differences of the logarithms.

The demand functions for livestock products were fitted by single equations methods, what Marschak (22) called the "uniequational complete model"-- a model in which all but one of the variables is predetermined. Fox used diagrams rather than sets of equations to depict the array of economic forces involved in price determination for particular farm and food products.

Fox hypothesized that the price of hogs and pork was a function of income, production, and consumption, with consumption as a function of only income and production. Weather was included as an explanatory variable, along with income, production, and consumption, in the beef and cattle relations.

In another study, Fox (14) developed a submodel of the agricultural sector. The submodel was incorporated into a complete model of the United States economy which was developed to explain the variations in GNP and its major components, as well as major price movements, employment, and wage rates.

Fox's quarterly submodel consisted of 15 equations which can be divided into one block of eight equations focusing on the determination of farm market prices, and a second block directed toward the estimation of net farm income. Four endogenous variables to be explained by the submodel included production, consumption, retail price, and farm price. The data used for the model were quarterly observations for the period 1947-1960. Since the primary focus of our study is livestock prices and quantities, only the sections of the model relating to livestock products were examined.

There was no disaggregation or explanation of how prices or quantities of individual livestock products are determined for the consumer demand equations. Rather, aggregate indices based on the retail dollar value of the livestock component of the food market basket were developed. Using the least squares method, these indices were regressed on variables such as time, the dependent variable lagged one quarter, and the sum of an index of per capita consumption of food livestock products, retail value of the crop component of the food market basket, an implicit price deflator for personal consumption expenditures on nonfood goods and services, and deflated per capita disposable income.

The submodel also included equations to explain determination of farm prices for food products. One equation was a marketing margin identity where farm price of the livestock component is the difference between prices at the retail level and marketing charges.

Harlow

In 1962, Harlow (17) published his recursive model of the hog industry. He developed a six equation model fitted by least squares using quarterly data from 1949 through 1959. Some of the endogenous variables were sow farrowings, hogs slaughtered, storage of pork, farm price of hogs, and retail price of pork. All price variables in Harlow's model were measured in prices deflated by the consumer price index. Corn price was considered exogenous to the equation system.

Harlow expanded the basic supply equation of the simple cobweb model into three equations to reflect some of the steps in the production process for pork. The number of sows farrowing were specified as a function of farrowings for the same quarter the previous year; the prices of corn, beef, and hogs for the fourth quarter of the previous year; and grain production (barley, oats, and grain sorghum). The number of hogs slaughtered was hypothesized to be

functionally dependent on farrowings lagged two quarters, a dummy variable used to allow for unusual conditions Harlow observed in the third quarter of each year, and time, which was intended as proxy for the increasing number of pigs saved per sow. In Harlow's model, quantity of pork produced depended on the ratio of pigs saved per sow in the fall of the preceding year to the number saved in the spring, and current hog slaughter.

On the demand side, Harlow specified retail price of pork as determined by current per capita values for pork production, pork storage, beef and poultry production, and deflated discretionary income. Harlow also included a seasonal index and a dummy variable to account for an observed post-1955 shift in pork demand.

The initial modeling attempt generated serial correlation in the residuals. To correct for this, Harlow altered the model slightly by including more explanatory variables in the equations. For example, he added hog prices lagged one quarter to the equation describing hog slaughter. Corn price for the fourth quarter of the previous year was added to the production equation, while a dummy variable was added to the storage equation. Harlow modified the retail and farm prices equations for pork and

hogs by adding lagged farm price of hogs to the retail price relation and per capita pork storage to the relation for determining farm price of hogs. These changes resulted in a model that Harlow felt described the hog industry more adequately.

Langemeier and Thompson

In 1967, Langemeier and Thompson (21) published their study of demand, supply, and price relationships for the beef sector. They noted that of 18 studies either focusing or encompassing the beef sector, 13 emphasized the demand side and all but two specified supplies as predetermined. Their model, which consisted of 12 relationships, allowed for simultaneity between supply and demand. In the twelfth relation, Langemeier and Thompson specified the number of fed beef animals slaughtered to be of the single equation form. Some of the endogenous variables included in the model were weight per head of fed cattle slaughtered, supply of nonfed beef from domestic sources, imports of beef, and fed and nonfed beef prices on both the farm and retail levels.

The two-stage least squares method was employed in estimation of the simultaneously determined relationships. Ordinary least squares was used to estimate the relation for

number of fed beef animals slaughtered. In estimating their model, the authors used annual observations for the period 1947 through 1963.

Perhaps the most important aspect of the model developed by Langemeier and Thompson is their disaggregation, or breaking down, of beef into fed and nonfed components and estimation of separate demand and supply functions for each. Langemeier and Thompson compared their findings on price elasticity of total supply and price flexibilities of total demand with those of other studies. They noted that other analysts had underestimated income elasticity of demand for fed beef by focusing on all beef and not looking at the individual fed and nonfed beef components separately and also had overlooked the inferior income demand relationship for nonfed beef. Unlike other livestock modelers, Langemeier and Thompson did not include substitutes for beef in their demand equations.

Crom

In 1970, Crom (8) developed a price output model of the beef and pork sectors using quarterly data for the period 1955-1968. Crom envisaged a twofold use of his model. First, the model could be used to project prices and outputs in future time periods. It also could be used to simulate the effects of proposed changes in economic policy.

Crom's model included equations for estimating the behavioral relationships for marketings of beef and pork, basic commercial slaughter, meat production, imports, and supply of and demand for beef and pork.

Like Harlow (17), Crom specified the underlying structure of the pork sector (and beef sector as well) to be recursive in nature. Thus, his model is basically a recursive one with few simultaneous relationships. Following Langemeier and Thompson's lead, Crom disaggregated the beef sector into its fed and nonfed components. Crom assumed corn price to be determined by factors outside the system. Most of the other models reviewed in this chapter are similar in this respect. The basic functional relationships embodied in the model initially were estimated using ordinary least squares procedures.

There were two approaches used by Crom not usually found in similar models. The first is his use of a different equation for each quarter in specifying several of the functions, e.g., fed cattle marketing, average weight of fed cattle, and feeder steer prices. His reasoning was that use of different time lags or different explanatory variables in several cases necessitated a separate equation for each quarter. Other quarterly studies have used a

single equation but added quarterly dummy variables to allow for seasonal patterns.

The other major difference in approach used by Crom was his introduction of over 100 operating rules into the model after the initial run to correct for error or for development of unusual market situations. This reliance on operating rules could raise some doubt as to the adequacy of his equations in explaining the behavior and structure of the beef and pork sectors.

Later Econometric Models of the Livestock Sector

Three econometric models of the livestock sector are presented in this section. Two are largely quarterly models. For the third, annual data were used to estimate the model. All three generally are more detailed and complete than the earlier models, with perhaps the exception of Crom's work.

Freebairn and Rausser

In 1975, Freebairn and Rausser (15) used an annual simultaneous equation model to estimate demand and supply relationships for the fed beef, other beef, hog, and poultry sectors utilizing annual data for the time period 1956 through 1971. Although their model was originally developed

to analyze the effects of regulatory policies on beef imports, it can be used for forecasting purposes as well. In their model, Freebairn and Rausser estimated equations with two or more current endogenous variables using three-stage least squares. Other equations were estimated by use of ordinary least squares.

Freebairn and Rausser's econometric model describes the consumption, production, trade, and retail and farm prices of fed beef, other beef, pork, and poultry, as well as inventory levels of livestock used in the production of these products. Like Crom (8) and Langemeier and Thompson (21) they divide beef into fed and nonfed (they call this "other beef") components. Their definition of fed and nonfed beef is similar to that of Crom, that is, fed beef is defined to be meat from feedlot cattle, while the other beef category is composed of meat from cull cows, and range fed and imported beef. Langemeier and Thompson (21) used a slightly different classification scheme; they defined fed beef as steer and heifer beef while nonfed was composed of cow and imported beef. Freebairn and Rausser's assumption of an exogenous corn price was similar to what was done in earlier models. They assumed imports of beef to be exogenous, unlike Crom (8) and Bain (2) whose model is reviewed in the following section.

In attempting to deal with expected and anticipated price variability, Freebairn and Rausser developed expected farm price variables. A three-year moving average standard deviation of current and historical prices was used as a measure of anticipated price variability. The same specification was used for all equations on the assumption that producer price expectations are formed in a similar fashion for all commodities.

Bain

In 1976, Bain (2) developed an econometric model of the beef and pork sectors. The model was estimated using quarterly data for the period 1958 through 1974. Bain employed ordinary least squares to estimate the unrestricted reduced forms, explaining that the primary role foreseen for his model was that of forecasting and policy formulation. This would require the reduced forms of the equations.

Bain's model generally was a quarterly model (some equations were annual). The model was divided into five components, the production of beef, trade in meat, stocks of beef and pork, supply of pork, and demand for beef and pork. These sections were then integrated and run over six and 12 year periods using only the base year data for the endogenous variables and actual or predicted values for the independent variables.

Bain's model is similar to Crom's (8) in several respects. For example, both designate the wholesale level as the level where the initial adjustment of meat prices takes place in response to shifts in demand or supply. They also both specified a recursive framework for their models. In addition, there was similarity in their treatment of meat stock relations. Grain prices--specifically corn prices--were considered to be exogenously determined although Bain made the point that there should, ideally, be relations explaining determination of feed prices.

Bain included in his study some of the intermediate stages of his modeling efforts. This is something not done in most of the other models, with Harlow being one exception. Bain also included the derivation of the reduced forms for some of his equations. Perhaps the most useful aspects of Bain's study in terms of the development of the model for this study was the attention to detail and careful delineation of data sources.

Arzac and Wilkinson

In 1979, Arzac and Wilkinson (1) developed an econometric model of the United States livestock and feed grains markets using data for the 1957-1975 time period. Like Bain (2), some of their equations were estimated using

annual or semiannual data, but most were quarterly. Their model was designed to provide quarterly forecasts for such variables as livestock and grain production and prices, retail-producer price spreads for meat products, and consumer demand for meat. Ordinary least squares was used for the structural equations not characterized by simultaneous determination of the endogenous variables. Truncated two-stage least squares was used to estimate all the other equations.

Their 42 equation model is divided into five blocks: (1) consumer demand for meat (fed and nonfed beef, pork, and poultry); (2) retail and producer relations; (3) livestock production, inventory, and supply relations; (4) demand and supply of feed grain; and (5) market clearing equations and identities.

Unlike the other models reviewed in this chapter, Arzac and Wilkinson treated grain prices as endogenous. They also included relations to explain the determination of domestic corn demand, corn price, acreage planted for corn, and corn production. Other major differences between this model and other livestock models include Arzac and Wilkinson's use of quarterly rather than annual data, and the fact that they do not use a per capita basis for the

consumer demand equations. With the exception of these differences, this model is quite similar to that developed by Freebairn and Rausser (15).

Conclusions

Each of the abovementioned works has contributed to the development of econometric modeling in general and to this particular project as well. The most important work for the purposes of this study is that of Arzac and Wilkinson. It had the most complete specification of the livestock and feed grain markets, and it was based on quarterly data.

There is some disagreement among researchers as to whether some variables should be considered exogenous or endogenous. Cron (8), Freebairn and Rausser (15), and Bain (2) had grain prices as exogenous in their livestock models. Others, for example Arzac and Wilkinson (1), included a series of equations which serve to explain corn price levels (corn is usually considered the principal feed grain in livestock production), domestic corn demand, and corn production. Bain's determination of corn price as exogenous in his model is rather interesting considering his comment that while both government supports and export demand have been important in influencing grain prices, some feedback

THE ECONOMIC MODEL

For this study, the variables are divided into two groups, namely endogenous and exogenous. Endogenous variables are those variables determined within the system under study, while exogenous variables are determined outside the system. For example, the farm price of fed beef is endogenous to the model of the livestock industry developed for this study, while disposable income is considered to be determined outside the livestock sector and designated as exogenous for this study. The variables used in this model are listed and briefly described in Table 1.

There is some disagreement among researchers as to whether some variables should be considered exogenous or endogenous. Crom (8), Freebairn and Rausser (15), and Bain (2) had grain prices as exogenous in their livestock models. Others, for example Arzac and Wilkinson (1), included a series of equations which serve to explain corn price levels (corn is usually considered the principal feed grain in livestock production), domestic corn demand, and corn production. Bain's determination of corn price as exogenous in his model is rather interesting considering his comment that while both government supports and export demand have been important in influencing grain prices, some feedback

TABLE 1. Description of Variables

Endogenous Variables:

Variable Name	Description
IH	Number of pigs on feed
IP	Cattle and calves on feed
IP4	Prior placement of cattle and calves on feed
KB	Inventory of beef cows
KC	Net calf crop
KH	Sows kept for breeding
Mi	Retail producer price spread, $i=1-4^*$
PFi	Producer price of meat, $i=1-4$
PF5	Price of feeder steers
PRi	Retail price of meat, $i=1-4$
SC	Calves slaughtered
SC4	Prior calf slaughter
SF	Sows farrowing
XDiPC	Per capita demand for meat, $i=1-4$
XSi	Meat production, $i=1-4$
Zi	Real retail price of meat, $i=1-4$

Exogenous Variables:

Variable Name	Description
B1	Choice beef by-product allowance
B3	Pork by-product allowance
CPI	Consumer price index
DP	Dressing percentage for hogs
EXi	Exports of meat, $i=1-4$
ID	Dairy herd replacement
IMXi	Imports of meat, $i=1-4$
KD	Inventory of dairy cows
LP	Index of productivity in poultry production
PF	Support price for corn
PG1	Corn price
POP	Population of the United States
PSPS	Pigs saved per sow
Qt	Quarterly dummy variables, $t=1-4$
W	Wage rate in meatpacking
W2	Wage rate in poultry dressing
Y	Disposable personal income
YZ	Real disposable personal income

*1=fed beef, 2=nonfed beef, 3=pork, 4=poultry

from animal production to feed prices is desirable in a more general model of the livestock industry.

Econometric livestock model builders also differed as to which of the three price levels (retail, wholesale, or farm) they chose to use in equations estimating the demand for meat. Harlow (17) and Freebairn and Rausser (15), among others, chose the retail price level. Their reasoning was that in the short run prices of the more basic commodities are regarded as derived primarily from the price for the retail product. Bain (2) and Crom (8) both considered the wholesale level to be the appropriate price level on which to focus their analysis of demand for meat. According to Crom, consumers are price takers and quantity adjusters, and the wholesale market level probably represents a true interaction of supply and demand in a bargaining sense. While there is merit in both points of view, for this study the retail price level has been used for the meat demand equations.

The Economic Model

The model is divided into four sections, three of which deal with different components of the system while the fourth contains market clearing equations or identities.

The three components are livestock production, inventory, and supply relations; consumer demand for meat; and retail and producer price relationships.

Livestock Production, Inventory, and Supply Relations

This section of the model is made up of three distinct but related components. They include production relations for beef and pork, inventory relations for beef and pork, and supply equations for beef, pork, and poultry. Due to the relatively short lag between decisions to produce poultry and realization of a ready-to-slaughter animal, it was decided that inclusion of an inventory relation for poultry was unnecessary.

Beef Production Hunt (19) made the observation that in the United States beef industry there essentially are two production processes. One process results in what is known as fed beef. This category includes beef that is graded good, choice, or prime. The other processes results in nonfed beef. Hamburger and flaked or processed meat are included in this category.

Both processes begin on the farm or ranch where feeder cattle are produced from the cow herd. Cows are kept in the herd to continue the breeding process until they are no longer productive. They then are culled from the herd

and sold for slaughter. Meat produced from these animals is referred to as nonfed beef. The other primary sources of nonfed beef are cows culled from dairy herds, heifers reared for replacement but then culled, and steers and heifers fattened on forage. Feeder cattle are placed in feedlots to be fattened for slaughter and emerge as fed beef.

Bain (2) presented a diagram which shows the workings of the beef production process, along with an appropriate time scale which is measured in three-month units. This diagram, Figure 1, shows the temporal ordering of beef production. The sequence is dictated by the physical processes involved in breeding and fattening cattle. The diagram also provides an indication as to which phases of the production process must be included in the analysis in order to obtain a forecasting model for beef output.

The steps in the figure represented by solid lines from period "t-9/10" through "t-2" are largely carried out by ranchers. They determine the number of cows bred and whether to sell the offspring as feeder cattle or finish them for slaughter on forage. Feedlot operators purchase feeders at about "t-2." These then become fed beef at "t."

If one accepts the diagram as a true depiction or representation of the processes involved in production of beef, then the model would need an equation or relation for each of these processes in order to be complete. Due to resource, time, and data limitations this was not considered feasible. However, this section of the model contains relations for what are considered to be the more important processes. These include beef cow inventory, net calf crop, calves slaughtered, placements on feed, and production of fed and nonfed beef. Dairy cow inventory and dairy herd replacements were considered to be exogenous.

Beef Cow Inventory Freebairn and Rausser (15) described the inventory of beef cows as a function of current price of other beef (similar to nonfed), farm price of feeder calves, and a three-year moving standard deviation of calf prices. Crom's (8) inventory equation indicated that cow numbers were a function of lagged feeder cattle prices, lagged cattle inventory values, and changes in inventory.

The equation for the inventory of beef cows is shown below. This equation is one of the few in the model that is not based on quarterly data. The USDA reported the inventory of beef cows on an annual basis for most of the period of this study.

Beef Cow Inventory = $f(\text{lagged feeder cattle price, lagged producer price of nonfed beef, lagged beef cow inventory})$

Given the above functional form, it is expected that the values of feeder steer prices having the most influence on the producer's inventory decision would be those occurring in the third and fourth quarters of the previous year, and that the sign of both coefficients is positive. Expectation of a positive relationship between level of beef cow inventory and price of feeder cattle appears logical. The expected sign of the lagged producer price for nonfed beef is negative. Therefore, one could expect that a relatively high producer price for nonfed beef, one component of which is cows culled from the breeding herd, could influence producers to slaughter some of their breeding stock. The lagged dependent variable is expected to have a positive sign for its coefficient and to be a major factor in determining current inventory levels.

Tomek and Robinson (25) suggest that there is a distinction that is sometimes made between the traditional supply function of economic theory and a "response relation." The traditional supply curve specifies a price-quantity relation with all other factors held constant. The more general response relation specifies the output response

to a price change without holding other factors constant. Therefore, the response could involve both a movement along a supply curve and shifts in supply.

The response relation is not a reversible function in the sense that a supply curve is reversible. Actually, the supply response elasticity is likely to be different for an increase in price as opposed to a decrease in price. An example of how traditional economic supply functions differ from "response relations" can be found in an analysis of the beef cow inventory relation. The hypothesis is that there is a direct relation between beef cow inventory levels and the price of feeder cattle. A decrease in feeder cattle price would lead to a decrease in inventory and an increase in the price of fed steers would lead to an increase in inventory levels. It cannot be said, however, with great surety that equal decreases and increases would result in changes of equal absolute magnitude. It is relatively easy to reduce inventory levels by culling a larger than normal amount of the breeding herd, however, it takes much longer to realize the decision to increase the breeding herd.

Net Calf Crop The next equation for this model involves determination of the net calf crop, that is the difference between calf births and deaths.

Net Calf Crop = $f(\text{lagged beef cow inventory and lagged dairy cow inventory})$

This is simply considered to be a function of the sum of beef cow inventory and dairy cow inventory in the previous year. Freebairn and Rausser (15) had an identical specification for the variable which they called calves raised.

Calves Slaughtered The number of calves slaughtered each quarter is a function of the number of dairy cows during the previous time period and the current price of feeder steers. The functional notation is given below.

Calves Slaughtered = $f(\text{current price of feeder steers, lagged dairy cow inventory})$

The number of calves slaughtered is expected to vary inversely with feeder steer prices. The reasoning behind this is that feeder steer prices represent the alternative use to which the calf could be put, i.e., placed in a feedlot and fattened for slaughter at a later date. It is expected that there is a positive relation between calves slaughtered and lagged dairy cow numbers. Freebairn and Rausser (15) base this on the assumption that most of the calves slaughtered are dairy calves, hence dairy cow inventory levels the previous time period are used as a

proxy variable. As can be observed in Table 2, both dairy cow numbers and the number of calves slaughtered have been declining over the past several years. The correlation between the two series would tend to reinforce the relation hypothesized above, i.e., that the number of calves slaughtered and dairy cows in inventory are related positively.

TABLE 2. Number of Dairy Cows and Number of Calves Slaughtered

Year	Dairy Cows (000 head)	Calves Slaughtered (000 head)
1960	19527	8225
1961	19271	7701
1962	18963	7494
1963	18379	6833
1964	17647	7254
1965	15380	7420
1966	14490	6647
1967	13725	5919
1968	13115	5443
1969	12550	4863
1970	12091	4072
1971	11909	3689
1972	11778	3053
1973	11651	2249
1974	11297	2987
1975	11220	5209
1976	11071	5350
1977	10998	5517
1978	10896	4170
1979	10790	2824
1980	10779	2588
1981	10860	2798

Placements of Cattle on Feed The feedlot operator determines the number of cattle to be placed on feed, basing this decision on a number of factors. One factor affecting the placement decision is the price of feeder cattle. Other factors are grain prices and prices of other inputs during the feeding period (normally four to six months). The feedlot operator also considers the expected price of fed cattle at the time cattle on feed reach a marketable weight range.

Freebairn and Rausser (15) reported that their attempts to estimate the relation explaining decisions to place cattle in feedlots had not been entirely successful. They found that inclusion of feeder calf prices failed to support the hypothesis that the cost of the feeder calf input influences decisions in a significant way. The final form of their relation included farm price of fed beef, farm price of corn, and supply of feeder calves.

Bain (2) hypothesized that placements of cattle on feed were determined by fed beef price, expected corn price, and lagged beef calf inventory. He reported that some experimentation was involved in specification of the expectations function for corn and fed cattle prices. The final result was that the current value for both variables

appeared to largely determine expectations, and that there was no improvement from fitting polynomial lag functions.

Crom (8) explained that he estimated each quarterly equation separately due to the fact he employed different lagged inventory variables for each quarter. The beef cow inventory variable was used as a proxy for the beef calf crop in equations for the first and fourth quarters of the year. In three of the four quarters he included the beef/corn price ratio. Crom indicated that the steer price alone yielded a better second quarter estimate.

For this model, a functional form that is quite similar to that used by Arzac and Wilkinson (1) is proposed.

$$\begin{aligned} \text{Cattle Placed} = f(\text{farm price of fed beef, price of corn,} \\ \text{on Feed} \quad \text{calf slaughter for past four quarters,} \\ \text{including gestation time, net calf crop minus dairy herd} \\ \text{replacements, lagged placements}) \end{aligned}$$

It is expected that a positive relation exists between placements and fed cattle price since increases in fed cattle prices would tend to encourage placements. Increases in the price of corn increases the cost of feeding cattle and, thus, decrease placements. A negative relationship between placements and prior calf slaughter is expected. The difference between net calf crop and dairy herd replacements serves as an indicator of supplies of calves available for placement and would exhibit a direct relation

with placements on feed. Lagged placements on feed (number placed on feed in previous time periods) also is included in this relation and is expected to have a positive relationship with current placements.

Price of Feeder Steers Calves that are not slaughtered for veal are reared as replacements for breeding stock, for dairy herd replacements, or are carried on for fattening on forage or placement in feedlots. The beef breeder, therefore, has the alternative of selling his (or her) cattle when they reach the desired feeder age and weight range or carrying them on until they reach a suitable weight and condition for slaughtering.

Due to the biological nature of livestock production including gestation time, weaning time, etc., the supply of calves available as potential feeder cattle is fixed. That is,

$$\text{Supply of Feeder Steers} = f(\text{calves available})$$

On the demand side, feedlot operators determine the number to be placed on feed largely based on current price of feeder cattle, expected input costs, and the expected price of their output (fed beef) at the time when these animals placed on feed would reach a marketable weight.

Demand for Feeder Steers = $f(\text{current price of feeder steers, expected fed cattle price, current corn price})$

The input price variable, corn, is chosen because of its relative importance in feeding costs.

The alternative demand for calves consists of demand for slaughter calves. The functional form is as follows.

Demand for Slaughter Calves = $f(\text{current price of feeder steers, nonfed beef price})$

Current feeder steer price is representative of the opportunity cost of slaughtering and nonfed beef price represents the price of the final output, nonfed beef.

There is an identity for the supply of and demand for calves available. That is,

Quantity Supplied = Quantity Demanded of feeder calves +
of Calves Quantity Demanded of slaughter calves

Let $Q_{dfeeder} = B_0 + B_1PF_5 + B_2PF_{1E}(t+2) + B_3PG_1$

Where $Q_{dfeeder}$ is quantity demanded of feeder steers, PF_5 is price of feeder steers, $PF_{1E}(t+2)$ represents fed beef price expected two quarters in the future, and PG_1 is current corn price.

$Q_{dslaughter} = a_0 + a_1PF_5 + a_3PF_2$

$Q_{dslaughter}$ is quantity demanded of slaughter steers, PF_5 is price of feeder steers, and PF_2 is nonfed beef price.

Substituting quantities demanded of feeder and slaughter calves into the identity, where quantity supplied is equal to the two demands, gives the following.

$$Q_s = B_0 + B_1PF_5 + B_2PF_1E(t+2) + B_3PG_1 + a_0 + a_1PF_5 + a_2PF_2$$

Combining terms gives the following.

$$Q_s = (B_0 + a_0) + (B_1 + a_1)PF_5 + B_2PF_1E(t+2) + B_3PG_1 + a_2PF_2$$

The equation can then be solved for PF_5 :

$$PF_5 = - (B_0 + a_0)/(B_1 + a_1) - B_2/(B_1 + a_1)PF_1E(t+2) - B_3/(B_1 + a_1)PG_1 - (a_2)/(B_1 + a_1)PF_2 + 1/(B_1 + a_1)Q_s$$

With respect to the signs of the coefficients in the demand and supply equations, B_1 is expected to be negative, B_2 to be positive, B_3 to be negative; a_1 is expected to be negative and a_2 positive. The structural equation for the reduced form specifying feeder steer price as the dependent variable, therefore, is as follows.

$$\begin{array}{l} \text{Price of Feeder} = f(\text{expected fed beef price, current corn} \\ \text{Steers} \quad \quad \quad \text{price, current nonfed beef price,} \\ \quad \quad \quad \text{net calf crop minus dairy herd} \\ \quad \quad \quad \text{replacements, change in prior} \\ \quad \quad \quad \text{calf slaughter}) \end{array}$$

With respect to the expectations operator, for this study it will be assumed that expected fed beef price is well approximated by current price levels; therefore, no further experimentation was felt necessary, and the expected price

will be represented by the price that is current to the period during which producer decisions are being made. A direct relation between feeder steer price and expected fed beef price is hypothesized. The current corn price coefficient is expected to be negative, that is, an increase in the price of this input would depress prices feedlot operators would be willing to pay, and a decrease would tend to increase the feeder steer price. Higher expected nonfed beef prices could encourage producers to hold back calves for forage fattening, so a positive relation between the nonfed beef price variable and feeder steer price is expected. The variable related to the supply of feeder calves, net calf crop minus dairy herd replacements, should have an inverse relation to prices for feeder steers. A variable to measure the difference between current calf slaughter and calves slaughtered one year previously also is included in the equation; the relation between this variable and price of feeder steers is expected to be a direct one.

Bain (2) presented the derivation for an unrestricted reduced form equation for both placements and feeder cattle price. The final form of his feeder cattle price equation included current fed and nonfed beef prices, lagged fed beef price, and current corn price. Crom (8)

presented separate functions for feeder animal prices for each quarter of the year. He estimated that the price of feeder cattle was a function of choice steer price (fed beef) and a variable he called gross price margin on steers just marketed (an identity weighting current fed steer price and feeder price lagged two quarters). Freebairn and Rausser (15) included price of fed cattle and changes in calf inventory as their explanatory variables for feeder prices.

Production of Fed Beef Several of the models reviewed for this study specified fed beef production to be a function of lagged placements alone. For example, Freebairn and Rausser (15) and Bain (2) both used this relation to explain fed beef production. Hunt (19) specified farm level supply of fed beef to be a function of fed beef price, number of cattle on feed at the beginning of the year, grain price, and lagged feeder cattle price. This form is closest to the functional format given below.

Fed Beef Production = $f(\text{fed beef price, corn price, placements on feed lagged two quarters})$

According to economic theory, there is a positive relation between production and commodity price, therefore, fed beef production is expected to vary directly with its own price.

Corn price again represents the cost of inputs to the production function for fed beef, and it should exhibit an inverse relation with production. According to Bain (2), lagged placements on feed would be probably the most important determinant of fed beef production. The relationship between the two variables is expected to be a direct one.

Production of Nonfed Beef The primary sources of nonfed beef are cows culled from breeding and dairy herds and steers and heifers not fattened in feedlots. Cows can be culled from breeding herds when they are no longer productive or when producers decide to reduce the size of their breeding inventory. Nonfed heifers can be retained for breeding, sold for slaughter, or placed in feedlots. Nonfed steers may be sold for slaughter or placed in feedlots (See Figure 1).

Langemeier and Thompson (21), the first researchers to publish a disaggregated beef model, included nonfed beef price, lagged fed beef price, beef cow inventory, range conditions the previous year, and farm price of milk in their relation explaining nonfed beef production. They reported that each of these variables exhibited inverse relationships with the nonfed beef supply variable in their

estimated model, with milk price not appearing to be significant. Freebairn and Rausser (15) specified production of other (nonfed) beef to be dependent on its own price, lagged feeder prices, a moving standard deviation of feeder prices, and lagged range cattle inventory. Bain (2) included beef and dairy cow inventory and lagged beef calf inventory in addition to lagged prices for nonfed beef, corn, and feeder cattle, as well as lagged placements.

The specification of nonfed beef production is as follows.

$$\begin{array}{l} \text{Nonfed Beef} = f(\text{price of feeder steers, weighted} \\ \text{Production} \quad \text{combination of beef and dairy cow} \\ \quad \quad \quad \text{inventory, of calves available, average} \\ \quad \quad \quad \text{placements, nonfed beef price}) \end{array}$$

Arzac and Wilkinson (1) specified a similar function but did not include nonfed beef price.

It is expected that nonfed beef production varies inversely with feeder steer prices. Feeder steer price represents one of the production alternatives or opportunity costs of not feeding cattle. The variable representing the availability of one of the sources of nonfed beef, the weighted beef and dairy cow inventory, would be expected to vary directly with supply of nonfed beef. This weighting is similar to that used by Freebairn and Rausser (15) in their equation explaining nonfed beef production. A large number

of calves available could, depending on feeder prices and other factors, be expected to increase nonfed beef production. Increased average placements would decrease the supply of steers and heifers and also might encourage retention of breeding cattle. Finally, increases in prices of nonfed beef could be expected to encourage nonfed slaughtering.

Pork Production As mentioned earlier, one of the hypotheses of this study is that there has been structural change in the various components of the livestock-meat industry over the past few years. Van Ardsdall (48) conducted a survey of hog producers in 1975. He concluded that much change indeed has occurred in the factors affecting or influencing cost of production and supply response in recent years, and that accelerated rates of change are probable in the future. He identified three major types of enterprises that are involved in the hog production process. They are feeder pig production, finishing or feeding of hogs and pigs, and farrow to finish operations.

Bundy and Diggins (6) identified seven important factors affecting hog production. They are supply and price of live hogs, consumer demand for pork and lard,

availability of feed supplies, supply and price of competing meat products on the consumer market, hog-corn price ratios, swine disease outbreaks, and world economic conditions. Bundy and Diggins also outlined divisions of hogs and pigs into market classes by weight, use, and sex (Table 3).

TABLE 3. Market Classes of Hogs and Pigs

Use	Sex	Weight
Hogs:		
Slaughter hogs	barrows, gilts	under 180 - 300+
	sows, others	200 - 600+
Feeder & stocker hogs	barrows, gilts	120 - 180
Pigs:		
Slaughter pigs	All classes	under 30 - 100
	barrows, gilts	100 - 200
Feeder pigs	barrows, gilts	under 80 - 120

For the section of this model dealing with pork production, it was decided to use two approaches. The first approach is the more traditional one and is similar to that used by

Harlow (17), Crom (8), Freebairn and Rausser (15), and Bain (2). The second specification attempt is similar to that used by Arzac and Wilkinson (1).

In the first approach, two relations are specified. The first is an inventory relation in which the variable to be explained is the number of sows farrowing. The relation for the model is as follows.

$$\text{Sows farrowing} = f(\text{lagged hog price, lagged corn price, lagged fed beef price, lagged farrowings})$$

The number of sows farrowing is expected to vary directly with hog price and inversely with grain (corn) price. Fed beef prices represent alternative uses of resources used in production of pork and would be expected to have a negative coefficient. Current farrowings are expected to vary directly with farrowings of the previous time period.

Bain (2) indicated that his research did not support the use of fed cattle prices in the farrowing relation, suggesting that hog producers did not, as set forth by Crom, Harlow, and others, also engage in cattle feeding. On the other hand, one finding resulting from Van Arsdall's survey of hog producers was that two-thirds of all farms producing hogs also reported having other livestock or poultry enterprises. Beef cows or cattle feeding enterprises were present in over 90 per cent of these farms reporting other livestock (48).

The pork production relation below is similar to that of Crom (8), Harlow (17), Bain (2), and Freebairn and Rausser (15).

$$\text{Pork Production A} = f(\text{lagged sows farrowing, pigs saved per sow, dressing percentage, corn price, hog price})$$

The first two variables, lagged farrowings and pigs saved per sow, are believed to be the most important determinants of pork production. Both variables are expected to influence pork production directly. Corn price is expected to vary inversely with production. The reasoning here is that increased corn prices will serve to decrease slaughter weights and thereby influence the quantities of pork produced. A change in pork prices will affect decisions made by producers as to culling of sows from the breeding herd and retention of gilts to add to breeding herd inventory.

There are two ways to look at the possible effects of change in pork prices on pork production. One is that an increase in pork prices could encourage producers to slaughter and either increase culling rate or decrease number of gilts retained for breeding. Another possibility is that pork producers would see a price rise as a signal that prices will continue an upward trend and would decide

to reduce culling of sows and retain more gilts in order to increase production in the next few quarters. While some studies included a trend variable to reflect the upward movement in the dressing percentage of hogs, in this study the actual dressing percentage will be calculated and utilized.

A second specification of inventory and production relations for the hog sector involves three separate equations. The first relation is for number of sows kept for breeding and is presented below.

$$\begin{array}{l} \text{Sows Kept for} = f(\text{lagged corn price, lagged pork price,} \\ \text{Breeding} \quad \quad \quad \text{lagged fed beef price, lagged inventory}) \end{array}$$

It is expected that corn price and number of sows kept for breeding will vary inversely since feed prices are the major component of production costs. Bundy and Diggins (6) indicated that feed costs accounted for 80 per cent of total costs and would, therefore, be a major influence on the profitability of producing hogs and pigs. Pork prices lagged two quarters reflect output prices at the time the farrowing or breeding decisions are made and are expected to directly influence inventory size. Fed beef prices would have an inverse relation with number of sows kept for breeding purposes as feeding of cattle would represent an alternative to production of pork. Current inventory is

expected to vary directly with lagged inventory. The rationale here is simply that if one has a large beginning inventory it is quite reasonable to assume that ending inventories will be large also.

The next relation deals with placement of pigs on feed.

$$\text{Pigs on Feed} = f(\text{lagged hog price, lagged corn price, current sow inventory, lagged placements of pigs on feed})$$

The expected signs of the coefficients are as follows. Placements of pigs on feed should be directly influenced by prices at the beginning of the feeding period, reflecting the prices prevailing at the time the placement decision is made. Since the number of pigs on feed is reported as of the end of the period, prices lagged one period were considered to be the appropriate ones to use in this relation. If corn prices increase, fewer pigs would be placed on feed. Conversely, if output prices are higher, placements would be expected to increase. The number of pigs on feed is directly influenced by the inventory of breeding stock and prior placements.

The third and final relation in this second specification of the pork production sector is the quantity of pork produced.

$$\text{Production of Pork B} = f(\text{current hog price,} \\ \text{lagged placements})$$

Here current production is specified as a function of the current farm price of hogs and lagged placements of pigs on feed. This form indicates that production is largely determined by placements in the previous quarter. The level of current hog price will influence producers to increase slaughter if price is high. If price is low, producers would perhaps tend to carry their inventory of fed hogs to a heavier weight or retain more gilts for breeding in hopes of having prices at a higher level two or more quarters in the future.

The second specification for the production relations is quite similar to that of Arzac and Wilkinson (1). These relations are similar in concept to those used to model cattle inventory and beef production, and they present a slightly different picture of the pork production sector. It could be argued that with the abovementioned structural changes in the hog production industry, they might present a clearer picture of the behavior of producers. For this reason, it is felt that this different approach merits inclusion in this preliminary stage, at least, of the modeling process.

Poultry Production Many of the models reviewed for this study did not include relations to quantify the production of poultry. Arzac and Wilkinson (1) and Freebairn and Rausser (15) did specify such a relation. The relation below is quite similar to their work.

Poultry Production = f(lagged poultry price, lagged corn price, productivity index, lagged poultry production)

Poultry production is expected to vary directly with broiler prices in the previous quarter. This one quarter lag reflects the fact that decisions on production are made by firms in the industry during the previous quarter. Corn price is lagged one quarter for this reason and is expected to have a negative coefficient. The productivity index is expected to have a positively signed coefficient and is included as a measure of the overall increasing efficiency in the poultry industry. Current production of poultry is expected to vary directly with lagged production.

Consumer Demand for Meat

Economic theory suggests that the quantity demanded of a good is determined by the price of that good, the prices of all other goods, and income. Ideally, all possible prices of substitutes and complements should be included in demand equations. Due to limitations on time

and lack of availability of adequate time series data, that is not possible. Therefore, the functional relationship listed below was used to explain the consumer demand for meat. Four categories of meat are included in this model. They are fed beef, nonfed beef, pork, and poultry. Since in this model demands for all four are based on the same variables, the general form of the equation will be given here.

$$\text{Per Capita Demand for Meat} = f(\text{Own real price of other meats, per capita disposable income})$$

The signs of the coefficients are expected to be negative for own price, positive for prices of other goods which are substitutes, and negative for prices of other goods which are complements. The sign of the income coefficient is expected to be positive if the good is a normal good and negative if the good is an inferior good.

The regression coefficients are expected to indicate that fed beef, nonfed beef, pork, and poultry are substitutes, to varying degrees, for one another. In some studies, researchers have hypothesized a somewhat complementary relationship between the various meats. This is explained by a desire for variety in the diets of consumers, an explanation not without some merit.

There are some differences in results reported by researchers with regard to whether nonfed beef should be considered a normal or inferior good. Langemeier and Thompson (21) and Freebairn and Rausser (15), for example, found a negative income-demand relationship for nonfed beef (hamburger or ground beef), while Hunt (19) and Crom (8) reported results indicating nonfed beef was a normal good.

Another area of difference found among livestock econometric models is in whether consumption is reported on a per capita or total basis. Most of the previous models used a per capita basis in order to, as Langemeier and Thompson (21) stated, minimize the problems of multicollinearity and the income effect. Of the studies previously reviewed, only Arzac and Wilkinson (1) used a total basis, perhaps to keep their equations linear.

Retail and Producer Relations

A price spread or marketing margin is defined as the difference between the price per unit at one stage of the marketing channel and the price of an equivalent unit of the commodity at a different level of the system. With regard to agricultural commodities or products, this price spread or margin is affected by a number of factors, one of which

is the degree of processing required for the commodity. For example, eggs require little processing. Accordingly, the marketing cost on eggs in 1962 accounted for about one-third of the average retail cost while the farmer or producer share represented about two-thirds. In contrast, the wheat farmer's share of the retail price of bread is small and the marketer's share is large (50).

There has been some disagreement as to whether the marketing margin is a constant or absolute amount, a percentage of retail prices or farm prices, or a combination of the two. Waugh (49) found that the price spreads or margins of several agricultural commodities tend to be somewhat between percentage and absolute amounts and are probably closer to absolute amounts than percentage. Freebairn and Rausser (15) allowed for both percentage and absolute amounts in their model.

Williams and Stout (50) indicate that there has been strong empirical evidence for a constant dollar margin between farm and retail prices with regard to meat prices. Williams and Stout also outlined several factors or forces that are responsible for changes and variations in marketing margins for meat. These include changes in hourly wages and other cost factors, changes in output or production of

marketing services, changes in physical productivity of factors, changes in the volume of marketings which affect both prices and costs, and lags or leads in prices at one level relative to another.

Two alternative forms for the retail-producer price relations are used in this model. The independent variables were chosen primarily on the basis of two criteria-- those that would appear to be the most influential in determining the marketing margin for the four meat groups and for which there were time series data for use in the statistical model. The two forms are shown below.

Marketing = f(retail price, wage rate in meat
Margin A packing or poultry dressing, by-product
in farm price, allowance)

Marketing = f(farm price, wage rate in meat packing
Margin B or poultry dressing, change in own farm
price)

Form A is similar to that used by Arzac and Wilkinson (1), while Form B is similar to that used by Freebairn and Rausser (15). A positive relation between own price (regardless of level) and marketing margin is hypothesized with both forms. A positive relation between wage rates, which are included as a measure of all costs of marketing, and the marketing margin is expected. Byproducts are defined as parts of the live animal that have value but are

not part of the retail cut of meat. A "true" spread or margin is not obtained unless the value or allowance for byproducts is included (3). Examples of beef and pork byproducts include hides, bones, fat, and edible and inedible offal. These by-product allowances are expected to exhibit negative or inverse relations with the marketing margin. The variable representing change in the farm price originally was used in an annual model by Freebairn and Rausser (15), either to measure changes due to seasonal factors or due to the fact that annual data were being used. They reported a negative sign on the coefficient, which implies an inverse relation between the margin and changes in farm price.

Market Clearing Equations and Identities

The following market clearing equations and identities complete the specification for the model. IP4 represents average placements on feed, while SC4 is the sum of calves slaughtered over the preceeding time periods.

$$IP4 = 1/4*(IP + IP_{t-1} + IP_{t-2} + IP_{t-3})$$

$$SC4 = (SC + SC_{t-1} + SC_{t-2} + SC_{t-3})$$

The margin identities simply state that the margin is the difference between the retail price and farm price of each meat product.

$$M_i = P R_i - P F_i \text{ where } i = 1-4$$

(Note: 1=fed beef, 2=nonfed beef, 3=pork, and 4=poultry).

Total consumer demand for meat plus imports of meat products is set equal to production of meat plus exports.

$$X D_i + I M X_i = X S_i + E X_i \text{ where } i = 1-4.$$

YZ and Zi represent real disposable income and real retail prices, respectively. That is each variable is deflated by the consumer price index (CPI).

$$Y Z = Y / C P I$$

$$Z_i = P R_i / C P I \text{ where } i = 1-4.$$

In the following sections, the estimated equations are examined. Parameter estimates and some measures of reliability are presented. There also is discussion of the principal economic implications of the estimates.

In addition to the estimates of the parameters, the results of equations estimated by OLS are accompanied by the coefficient of determination (R^2), the standard errors associated with each coefficient (given in parentheses below the estimated coefficients), root mean square error of the estimate (RMS), the standard deviation of the mean of the dependent variable (\bar{Y}), and the Durbin-Watson statistic.

THE ESTIMATED MODEL

The economic model of the United States livestock sector discussed in the previous chapter was estimated using ordinary least squares (OLS) and two-stage least squares (2SLS) procedures. Equations with only a single endogenous variable were estimated using ordinary least squares. For equations with two or more jointly endogenous variables two-stage least squares procedures were used for parameter estimation. For each of the simultaneous equations all the predetermined variables (the exogenous variables, lagged exogenous, and lagged endogenous variables) in the system were included as first stage regressors or instruments.

In the following sections, the estimated equations are examined. Parameter estimates and some measures of reliability are presented. There also is discussion of the principal economic implications of the estimates.

In addition to the estimates of the parameters, the results of equations estimated by OLS are accompanied by the coefficient of determination (R^2), the standard errors associated with each coefficient (given in parentheses below the estimated coefficients), root mean square error of the estimate (RMSE), the standard deviation of the mean of the dependent variable (SD), and the Durbin-Watson d statistic.

In situations where the lagged endogenous variable is included as a regressor, the Durbin-Watson h statistic is reported instead of the d statistic.

For equations estimated by use of 2SLS methods, the standard errors, root mean square errors (RMSE) and appropriate Durbin-Watson statistic (d or h), and standard deviation of the mean of the dependent variable (SD) are reported.

There was some experimentation involved in the selection of the final estimated equations. Some of the equations went through little or no revision while others required more analysis, especially with regard to the appropriate lag structure. Some of the preliminary specifications are included for those equations differing materially from the proposed specification given in Chapter 3.

The Consumer Demand Equations

The equations for the per capita demand for each of the four meat categories (fed beef, nonfed beef, pork, and poultry) were estimated by 2SLS procedures using quarterly data for 1960-81, and they are presented in this section. The dummy variables, the Q's, were included in each equation to allow for the impact of seasonality on consumption.

Per Capita Demand for Fed Beef

The estimated results for the fed beef demand equation (4.1) are given below.

$$XD1/POP = 6.590144 - 0.226239 Z1 + 0.142891 Z2 \quad (4.1)$$

(0.067) (0.051)

$$+ 0.075600 Z4 + 0.695869 YZ/POP$$

(0.053) (0.088)

$$- 0.857797 Q3 - 0.977797 Q4$$

(0.406) (0.407)

$$RMSE = 1.539 \quad d = 0.3014 \quad SD = 2.650$$

The economic interpretation of the positive sign of the nonfed beef price (Z2) coefficient is that there is some degree of substitutability between these two meat products. This would appear reasonable because, even though fed and nonfed beef are both beef products, table cuts (e.g., the better roasts and steaks in the case of fed beef) and hamburger (nonfed beef) are essentially different products. In preliminary estimations of this equation, pork price was not important in explaining determination of fed beef consumption. For this reason, the pork price variable was dropped from the final form of the equation. Results from estimation of this equation were similar to that obtained by Arzac and Wilkinson (1). Of the models reviewed for this study, only theirs included prices of nonfed beef, pork, and chicken as separate variables. Freebairn and Rausser (15)

combined pork and poultry prices into one variable they called "other meat," the sign of which was negative. Hunt (19) included veal, fish, and nonfed beef as substitutes in his fed beef demand equation. His results indicated that all three were significantly different from zero and were indeed substitutes to varying degrees for fed beef.

Per Capita Demand for Nonfed Beef

Results of preliminary estimation of the nonfed beef demand equation indicated that the most highly significant explanatory variables were nonfed beef price, pork price, and the dummy variables representing the third and fourth quarters of the year. The results of the the final estimation of the nonfed beef equation (4.2) are shown below.

$$\begin{aligned}
 XD2/POP = & 11.924756 - 0.156955 Z2 + 0.122175 Z3 & (4.2) \\
 & (0.020) & (0.016) \\
 & - 0.080740 Z4 + 0.466970 Q2 \\
 & (0.024) & (0.347) \\
 & + 1.731718 Q3 + 1.509230 Q4 \\
 & (0.347) & (0.347)
 \end{aligned}$$

$$RMSE = 1.133 \quad d = 0.480 \quad SD = 1.947$$

The own price sign was negative, as were the signs of all the other coefficients for own price in this section. The sign of the pork price coefficient was positive,

indicating that pork is a substitute for nonfed beef. In the preliminary runs of the model, the coefficients of fed beef price and of the income variable were found not to be significantly different from zero at the 0.05 level. For this reason they were dropped from the final form of this equation. Freebairn and Rausser (15), and Langemeier and Thompson (21) found nonfed beef to be an inferior good. The dummy variables for quarters three and four appear to be important in the determination of nonfed beef demand, which would indicate a seasonal pattern in consumption of this good.

Per Capita Demand for Pork

The results of the estimated equation for per capita demand for pork are similar to those reported in other studies and are presented below.

$$\begin{aligned}
 XD3/POP &= 19.145615 - 0.072708 Z1 + 0.114571 Z2 & (4.3) \\
 &\quad (0.041) \quad (0.033) \\
 &- 0.131263 Z3 + 0.195661 YZ/POP - 0.799280 Q2 \\
 &\quad (0.015) \quad (0.032) \quad (0.299) \\
 &- 1.252502 Q3 + 0.801720 Q4 \\
 &\quad (0.299) \quad (0.298)
 \end{aligned}$$

$$RMSE = 0.975 \quad d = 0.5024 \quad SD = 1.866$$

Using the relative sizes of the t-values as a measure of importance or influence, chicken prices do not

appear to be involved in determining pork consumption. The income effect is positive as hypothesized. The seasonal dummy variables indicated a definite pattern in pork consumption.

Per Capita Demand for Poultry

Based on the estimated results, per capita demand for poultry appears to be most strongly influenced by its own price, nonfed beef price, income, and seasonal factors. These results are presented below (4.4).

$$XD4/POP = 3.249189 + 0.026632 Z1 + 0.041658 Z2 \quad (4.4)$$

(0.018) (0.014)

$$+ 0.014438 Z3 - 0.174248 Z4 + 0.203919 YZ/POP$$

(0.012) (0.026) (0.039)

$$+ 0.936234 Q2 + 1.080472 Q3$$

(0.111) (0.110)

$$RMSE = 0.411 \quad d = 0.917 \quad SD = 1.883$$

Dummy variables for the second and third quarters appear to exert considerable influence on per capita poultry consumption. Arzac and Wilkinson (1) reported similar results. They also indicated pork was a substitute for poultry. The results reported by Freebairn and Rausser (15) indicated pork and beef (they combined fed and nonfed beef into a total beef variable) were substitutes for chicken, with beef the more important of the two.

Price and Income Elasticity of Demand

The own price and income elasticities of demand for the different meat categories included in the model are shown in Table 4. Estimates provided by Brandow (5) and George and King (16) from their studies of demand interrelationships are also included.

Examination of the results shown in Table 4 indicate that the estimates obtained from the demand equations used in this study do not differ markedly from those reported by other researchers. The differences often can be explained by use of different time periods for the study or by different specification of the demand equations. The use of different time periods for the studies would result in different mean values for the price and consumption variables. As most researchers use the mean values in computing the elasticities, the resulting estimated elasticities would be of differing magnitudes. Another possible source of variation in the estimated elasticities is the use of different estimation procedures for the models. For example, Hunt (19) used three-stage least squares (3SLS) while for this study 2SLS estimation procedures were used for most of the quarterly equations.

TABLE 4. Retail Price and Income Elasticities of Demand

Own Price Elasticities of Demand

Study:	Fed Beef	Nonfed Beef	All Beef	Pork	Poultry
B	- 1.15	- 1.17	--	- 0.61	- 0.74
L & T	- 0.98	- 1.24	--	--	--
H	- 2.03	- 1.35	--	--	--
F & R	- 0.83	- 0.43	--	- 0.84	- 0.84
A & W	- 1.86	- 2.97	--	- 0.87	- 0.98
G & K	--	--	- 0.64	- 0.41	- 0.78
Br	--	--	- 0.95	- 0.75	- 1.16

Income Elasticities of Demand

Study:	Fed Beef	Nonfed Beef	All Beef	Pork	Poultry
B	1.30	*	--	0.40	0.72
L & T	2.20	- 1.31	--	--	--
H	0.92	0.19	--	--	--
F & R	1.61	- 0.21	--	0.46	0.75
A & W	1.02	0.45	--	0.65	0.52
G & K	--	--	0.47	0.32	0.37
Br	--	--	0.29	0.13	0.18

*The income variable was not significant at the 0.05 level.

The studies cited above are:

B = Bennett
 L & T = Langemeier and Thompson
 H = Hunt
 F & R = Freebairn and Rausser
 A & W = Arzac and Wilkinson
 G & K = George and King
 Br = Brandow

The estimated own price elasticities of demand indicate that fed and nonfed beef have slightly elastic demands, while pork and chicken have relatively inelastic

demands. The signs of the income elasticities of demand are positive as were expected for three of the four meat groups in this study. The coefficient of the income variable in the nonfed beef demand equation was found not to be significant or different from zero at the 0.05 level. Therefore, a zero income elasticity estimate is assumed for nonfed beef.

Livestock Production, Inventory, and Supply Relations

In this section, the estimation results relating to production, inventory, and supply for the various livestock and meat categories are presented. All equations in this section were estimated using quarterly data for the period 1960-1981 except for the beef cow inventory (KB) and net calf crop (KC) equations which were estimated using annual data for the period 1959-1981.

Price of Feeder Steers

This partially reduced form equation (4.5), the derivation of which is given in Chapter 3, was estimated using 2SLS procedures. The results are presented below.

$$PF5 = 8.456177 + 0.164673 PF1 + 1.460456 PF2 \quad (4.5)$$

(0.073) (0.077)

$$- 1.216762 PG1 - 0.000236675 KCLG4ID$$

(0.552) (0.00006)

$$- 1.047497 Q2 + 1.277759 Q4$$

(0.393) (0.401)

$$RMSE = 1.495 \quad d = 1.1256 \quad SD = 17.277$$

Bain (2) and Arzac and Wilkinson (1) reported similar results with respect to the t-values for the farm price of fed beef (PF1) and farm price of nonfed beef (PF2) coefficients. This would indicate that feeder cattle prices are more responsive to the farm price of nonfed beef, which represents the opportunity cost of feeding cattle, rather than to the farm price of fed beef, which serves as an indicator of expected or future fed beef price. The corn price coefficient (PG1), which represents the principal input cost in feeding cattle, is significant and has the expected negative sign. The variable KCLG4ID represents the supply of calves available for placement on feed and varies inversely with the prices of feed steers (PF5) as expected. A smaller number of calves available for placement would tend to result in higher feeder steer prices, assuming demand has not changed. One of the variables in the original equation, prior calf slaughter (DSC), was omitted from the final version of the equation as it had a very low

t-ratio. Its omission did not result in significant changes in the other coefficients.

Beef Cow Inventory

The equation explaining the January 1 inventory of beef cows (KB) was estimated on an annual basis using OLS procedures. OLS procedures are appropriate since there were no jointly endogenous variables in the relation. The results of the estimation are presented below.

$$\begin{aligned} \text{KB} = & 3849.251 - 239.1647 \text{ PF5}_{t-2} - 405.1263 \text{ PF2} \quad (4.6) \\ & \quad (116.925) \quad \quad (197.454) \\ & + 0.905760 \text{ KB}_{t-1} \\ & \quad (.051) \end{aligned}$$

$$R^2 = .9524 \quad h = 2.487 \quad \text{RMSE} = 1306.938 \quad \text{SD} = 5566.18$$

Two different versions of this equation were estimated. The first was similar to that of Arzac and Wilkinson (1) and included PF5 lagged one period, PF5_{t-1} , as well as the three other variables found in the final form. After preliminary estimation, it was found that PF5_{t-1} was not significantly different from zero at the 0.05 level. This variable was dropped, and the equation estimated again. The final results are shown above.

The lagged dependent variable is highly significant and could be considered an important determinant of current inventory levels. Bain (2) and Arzac and Wilkinson (1)

reported similar results for their beef cow inventory equations. Bain explained that the year-to-year changes in the beef cow inventory are very small and, therefore, the lagged inventory value is considered a basic determinant of current numbers. Farm price of nonfed beef (PF2) was found to vary inversely with the beef cow inventory. This was as expected since a higher price for nonfed beef would, *ceteris paribus*, tend to encourage culling of cows from the breeding herd.

Net Calf Crop

The second equation estimated on an annual basis in this model was the equation explaining net calf crop (KC). Net calf crop was defined as the difference between the number of calves born and calf deaths each year. This equation (4.7) was estimated without an intercept term. The results are presented below.

$$KC = 0.827713 (KB + KD) \quad (4.7) \\ (153.53)$$

$$RMSE = 1299.604 \quad d = 0.666 \quad SD = 2690.01$$

The net calf crop is specified simply as a function of the sum of the beef cow and dairy cow inventories, KB and KD, respectively. Arzac and Wilkinson (1) and Freebairn and Rausser (15) specified similar functions. The results

obtained from estimation of this equation are quite similar to their results.

Placement of Cattle on Feed

The results of estimating the equation explaining the determination of number of cattle placed on feed each quarter (4.8) are shown below. The equation was estimated by 2SLS procedures.

$$IP = - 5109.3 + 48.736447 PF1 - 1054.27 PG1 \quad (4.8)$$

(8.104) (156.20)

$$+ 0.223714 KCLG4ID + 0.638002 IP_{t-1}$$

(0.030) (0.044)

$$- 465.672932 Q2 + 2200.072 Q4$$

(112.185) (122.421)

$$RMSE = 427.524 \quad h = - 1.259 \quad SD = 2008.928$$

Arzac and Wilkinson (1) reported obtaining similar results. Freebairn and Rausser (15) did not consider current fed beef and corn prices to be important variables in producers' placement decisions and left them out of their equation. In the initial estimation of this equation, SC4, prior calf slaughter, was included. It was found to have a very low t-ratio so it was dropped and the equation re-estimated. The remaining variables are statistically significant and have the expected signs. For example, high fed beef prices would tend to encourage producers to place

more cattle on feed, while high corn prices would be expected to have a depressing effect on placements. The values of the variable representing the number of calves available for placement (KCLG4ID) were computed by lagging the net calf crop four periods and subtracting dairy herd replacements. The relation between cattle placed on feed (IP) and this variable was positive as was expected. The dependent variable lagged one quarter was included as an explanatory variable to reflect the partial adjustment of placements.

Fed Beef Production

The estimated results for the fed beef production equation (4.9) are presented below. This equation was estimated by means of 2SLS, using quarterly data for the period 1960-1981. The production equations for nonfed beef, pork, and poultry were estimated by the same method.

$$\begin{aligned}
 \text{XS1} = & 728.625026 + 8.176867 \text{ PF1} + 0.305612 \text{ IP}_{t-2} & (4.9) \\
 & (2.028) & (0.015) \\
 - & 740.211150 \text{ Q2} - 622.558789 \text{ Q3} - 292.176643 \text{ Q4} \\
 & (75.039) & (71.377) & (69.568)
 \end{aligned}$$

$$\text{RMSE} = 228.804 \quad d = 1.2848 \quad \text{SD} = 688.143$$

In some of the models reviewed for this study (for example, Bain and Freebairn and Rausser) fed beef production was considered to be essentially predetermined by the number

of cattle placed on feed in previous time periods. The results obtained in this study indicated that while placements lagged two quarters, IP_{t-2} , was one of the most influential variables in determining fed beef production in the current quarter, fed beef price (PF1) also appears to have some influence on fed beef production. The size of the t-values associated with the coefficients of the dummy variables clearly indicate the presence of a strong seasonal pattern in production of fed beef. Corn price (PG1) was included in an early version of this equation but was dropped due to its very low t-value.

Nonfed Beef Production

This equation went through several revisions in an attempt to find the combination of variables and the lag structure which best explains the production of nonfed beef. Earlier versions were composed of combinations of current feeder cattle prices, lagged feeder cattle prices, various attempts at presenting fed beef profit margins (PF1 - PF5 and PF1/PF5) both in current and one-quarter lag forms, lagged own price ($PF2_{t-1}$), and current and lagged beef/corn price ratios (PF1/PG1) in addition to the other explanatory variables which were retained in the final form. Low t-values and incorrect signs indicated that those

earlier specifications were not adequately explaining the nonfed beef production decisions. The failure of these variables to significantly explain nonfed beef production could be related to the fact that fed and nonfed beef production are two different processes and, therefore, fed beef prices or ratios possibly should not be included in an equation modeling the structure of nonfed beef production. The final form of the equation (4.10) is presented below and is similar to that specified by Arzac and Wilkinson (1).

$$XS2 = - 3423.05 + 17.320526 PF2 + 0.036147 KB56KD \quad (4.10)$$

(4.263) (0.030)

$$- 0.309640 IP4 + 309.939559 Q3 + 378.386900 Q4$$

(0.035) (45.363) (46.376)

$$RMSE = 172.7418 \quad d = 0.8611 \quad SD = 421.318$$

The positive relation between nonfed beef production and price of nonfed beef is as expected. An increase in nonfed beef price perhaps influences producers to retain fewer heifers for replacements and/or increase the number of older and possibly less productive cows culled from the breeding herd. One could look at KCLG4ID as the supply of calves that could be either placed on feed or fattened on forage. The relation between nonfed beef production and this supply variable was found to be positive, as was expected. IP4 represents the average number of cattle

placed on feed and varies inversely with nonfed production. The t-values associated with the coefficients of the third and fourth quarter dummy variables indicate a strong seasonal pattern in nonfed beef production.

Number of Sows Farrowing

In Chapter 3, two different concepts for modeling pork production and hog inventory were proposed. For two reasons, the sows farrowing approach appeared to be the most compatible with the rest of the equations in the model. First, the pigs placed on feed - sows kept for breeding approach would necessitate use of semi-annual data while the number of sows farrowing were available on a quarterly basis. A second reason was that the pigs placed on feed - sows kept for breeding equations utilize data which became available in 1964. That would involve the loss of twelve observations from the data base. Thus, it was decided to use the sows farrowing approach for modeling pork production in this study. The estimated results of the final sows farrowing equation (4.11) are presented below.

$$\begin{aligned}
 SF = & 1292.577 - 170.7205 PG1_{t-2} + 8.4565 PF3_{t-2} \quad (4.11) \\
 & \quad \quad \quad (80.454) \quad \quad \quad (4.630) \\
 & + 0.465637 SF_{t-1} + 1419.31 Q3 + 265.4035 Q4 \\
 & \quad \quad \quad (0.066) \quad \quad \quad (93.184) \quad \quad \quad (79.892) \\
 RMSE = & 289.209 \quad h = - 1.6496 \quad SD = 574.331
 \end{aligned}$$

Modeling the producer decisions involved in this particular equation necessitated some experimentation with respect to lag structure. In Chapter 3, it was hypothesized that cattle feeding was an alternative enterprise to raising hogs (48). For this reason fed beef price (PF_1) was included as a regressor in an early form of the sows farrowing equation. This attempt produced disappointing results in that PF_1 was found not to be statistically significant at the 0.05 level. This variable, therefore, was dropped from the final form of the equation.

In specifying the lag structure for the price variables, it was considered important to include the prices that would be most influential on breeding decisions. These were determined to be corn and hog prices current to the period when the decisions were actually being made. Since there are about four months between breeding and farrowing, the price variables were lagged two quarters.

When the equation was estimated, the results were what had been expected. Corn price (PG_1_{t-2}) was negatively related to sows farrowing. The hog price variable (PF_3_{t-2}) was positively related to number of sows farrowing. Lagged farrowings (SF_{t-1}) were included because pig producers cannot fully adjust output within one

quarter to price changes taking place over the last three to six months. The size of the t-ratio associated with the second quarter dummy variable coefficient indicates that there is a strong seasonal pattern in sows farrowing. This finding is not totally consistent with the results obtained by Van Arsdall, who indicated that the hog industry has changed (48) and farrowing is now carried on year round by use of containment units to protect the sows and pigs during the winter months. One explanation of the different results is that there is still strong seasonality in the number of sows farrowing. Another possibility is that the data used to estimate this equation included enough observations from earlier years when there was a definite seasonal farrowing pattern due to weather conditions, etc., to outweigh the effect of the later observations. A third possibility is that the true situation lies somewhere between the two.

Pork Production

The estimated results of this equation (4.12), which are similar to those reported by Freebairn and Rausser (15), are presented below.

$$XS3 = - 9231.08 + 0.590411 SF_{t-2} + 6.432635 PSPS_{t-2} \quad (4.12)$$

(0.078) (2.225)

$$+ 103.146374 PG1 - 19.544658 PF3_{t-1} + 9888.666 DP$$

(66.675) (5.372) (1399.725)

$$- 200.530389 Q4$$

(105.253)

$$RMSE = 233.504 \quad d = 1.4401 \quad SD = 488.800$$

The sows farrowing variable lagged two quarters (SF_{t-2}) and the number of pigs saved per sow lagged two quarters ($PSPS_{t-2}$) are important determinants of current pork production. Current prices of corn and lagged hog price were found to be significant at the 0.05 level and their coefficients had the expected signs. One possible explanation of the negative sign of the hog price coefficient is that the anticipation of a lower price for hogs might induce producers to cull some marginally productive sows and/or not retain as many gilts for replacement purposes, thereby increasing pork production during the current quarter. Dressing percentage (DP) was found to be positively correlated with pork production. This variable appears to have had a significant influence on the amount of pork produced.

Poultry Production

As mentioned in Chapter 3, it was not deemed necessary to include an inventory relation for poultry due

to the relatively short time between production decisions being made and the realization of those decisions. The estimated results are given below (4.13).

$$\begin{aligned}
 XS4 = & - 43.3156 + 11.8023 PF4_{t-1} - 55.7955 PG1_{t-1} \quad (4.13) \\
 & \quad (2.193) \quad (17.548) \\
 & + 0.963606 XS4_{t-1} + 198.075851 Q2 - 175.953667 Q4 \\
 & \quad (0.018) \quad (14.333) \quad (14.097)
 \end{aligned}$$

$$RMSE = 53.218 \quad h = - 0.4708 \quad SD = 542.108$$

The price variables were lagged one quarter because the realization of production decisions takes approximately three months to occur. Broiler prices lagged one quarter ($PF4_{t-1}$) and corn prices lagged one quarter ($PG1_{t-1}$) were found to be statistically significant at the 0.05 level and had the expected signs. The lagged dependent variable was found to be very significant in determining production in the current quarter and had the expected positive sign. The productivity factor, LP, included in the first estimation was found not to be significant and was dropped from the final version of the equation.

Retail and Producer Price Relations

This block of equations describes the price margins or spreads which link farm and retail level prices for the

four categories of livestock and meat products in the model. The equations were estimated by 2SLS procedures utilizing quarterly data for the period 1960 through 1981.

In Chapter 3, two alternative specifications were given for the margin relations. After further analysis, it was decided to use the set of equations similar to those used by Arzac and Wilkinson (1). The results of the estimation are presented below.

$$M1 = - 2.0949 + 0.60176 PR1 + 0.03547 W - 0.37144 B1 \quad (4.14)$$

(0.024) (0.006) (0.100)

$$RMSE = 1.885 \quad d = 1.0543 \quad SD = 38.996$$

$$M2 = - 1.1612 + 0.7277 PR2 - 0.27796 B1 + 1.91464 Q4 \quad (4.15)$$

(0.010) (0.174) (0.849)

$$RMSE = 3.440 \quad d = 0.301 \quad SD = 28.002$$

$$M3 = 5.6311 + 0.5243 PR3 + 0.0286 W - 0.7662 B3 \quad (4.16)$$

(0.032) (0.005) (0.267)

$$RMSE = 2.0303 \quad d = 1.021750 \quad SD = 23.244$$

$$M4 = 5.2859 + 0.41839 PR4 + 0.0188 W2 + 0.71355 Q4 \quad (4.17)$$

(0.017) (0.002) (0.184)

$$RMSE = 0.735 \quad d = 1.5242 \quad SD = 7.293$$

In each equation, the signs of the coefficients were as expected. For example, an increase in wage rates would result in a higher margin or spread between farm and retail level prices for all four groups. In each equation the

retail price variable (PRi) was found to be highly significant.

In order to test for the possibility that seasonal patterns affect the margins, quarterly dummy variables (Q's) were added to each equation. Only in the margin equations for nonfed beef and poultry was any significant seasonal pattern detected, and both occurred in the fourth quarter. The fourth quarter dummy variables were, therefore, retained in the nonfed beef and poultry margin equations and the equations re-estimated.

Identities and Market Clearing Relations

In the final form of the model, the identities used were those proposed in Chapter 3 with one exception. Since it was decided that the calves slaughtered equation was not necessary for use in the model, the relation for prior calf slaughter (SC4) was dropped. The remaining identities used in the final form of the model are listed below.

$$IP4 = 1/4*(IP + IP_{t-1} + IP_{t-2} + IP_{t-3})$$

where IP4 was used to represent the average placements on feed.

The margin identities simply define the margin (Mi) as the difference between the retail price (PRi) and farm price (PFi) of each meat product.

$$Mi = PRi - PFi \quad \text{where } i = 1-4$$

(Note: 1=fed beef, 2=nonfed beef, 3=pork, 4=poultry).

Total consumer demand for meat (X_{Di}) plus imports of meat products (IM_{Xi}) was set equal to production of meat (X_{Si}) plus meat exports (EX_{i}).

$$X_{Di} + IM_{Xi} = X_{Si} + EX_{i}$$

Y_Z and Z_i represented real disposable income and real retail prices, respectively. That is, each variable was deflated by the consumer price index (CPI).

$$Y_Z = Y/CPI$$

$$Z_i = P_{Ri}/CPI$$

SIMULATION RESULTS AND EFFECTS OF IMPACT MULTIPLIERS

The second objective of this study was to simulate the model over the historical period (1960-1981) and evaluate its performance in predicting values for the endogenous variables. In this chapter, goodness of fit statistics for the simulation will be presented and the performance of the model in predicting values for key endogenous variables evaluated.

The second part of this chapter will consist of a discussion of impact multipliers and the long-term effects of changes in some of the exogenous variables on the endogenous variables. Emphasis will be on the effects of these changes on the various farm prices and production of fed and nonfed beef, pork, and poultry. The last part of this chapter will focus on the third objective, which was to analyze the effect of a policy change on some of the endogenous variables in the model. For this study, the effects of a reduction in corn price supports, as proposed in the federal government's 1985 Farm Bill, will be presented and discussed.

Model Simulation

In Chapter 4, the estimated results of equations which comprise this model were presented along with various statistics which measured how well each of these equations fit the data. In simulation, a model is tested to measure how well the system as a whole works together to reproduce the historical data. Sometimes it is the case that even though the individual equations fit the historical data very well, when they are combined to form a simultaneous equation model, the simulation results bear little resemblance to reality. Conversely, the individual equations might have a poor fit but the model as a whole may reproduce the historical time series very closely (24).

Solution Procedures

The use of a per capita basis and deflated retail prices for the demand equations caused the model developed for this study to be nonlinear in the meat demand variables. For this reason, standard algebraic solution techniques, such as matrix inversion, could not be applied. Therefore, two numerical techniques for solving the model were considered for use in this study. One was the Gauss-Seidel procedure and the other was Newton's method. Both are

iterative techniques which can be used when the system includes some nonlinear equations.

Each procedure has its strengths and limitations. While the Gauss-Seidel method does not require inversion of matrices, use of derivatives, or other sophisticated numerical methodology, it is very sensitive to which dependent variable is normalized and the ordering of the equations. Newton's method does involve use of derivatives but it orders the equations and can solve even implicitly defined equations. Newton's method was selected for use in simulating this model over the historical period.

Simulation Results

It is important to be able to evaluate the performance of simulation models. One way to test the performance of the model is to perform an historical simulation and examine how closely each predicted endogenous variable tracks its corresponding actual value of the historical data series. One quantitative measure that is often used is the root mean squared simulation error (RMS error). This is defined as

$$\text{RMS error} = \sqrt{1/T \sum (P_t - A_t)^2}$$

Where P_t = predicted value of the endogenous variable

A_t = the actual value

T = number of periods in the simulation

TABLE 1 The RMS simulation error is thus a measure of how the simulated variable deviates from its actual time path. The RMS simulation percent error, which is defined below, is another measure that is often used to test model performance.

$$\text{RMS percent error} = \sqrt{1/T \sum ((P_t - A_t)/A_t)^2}$$

The RMS simulation errors in percentage terms obtained from simulating the model over the period 1960-1981 are presented in tabular form below.

The model was simulated over the historical period beginning with the second quarter of 1960 and ending with the third quarter of 1980. Normalized retail price variables were used in the simulation, meaning that the demand equations were re-estimated with price as the dependent variable rather than the other jointly endogenous variable, per capita consumption. For simplification, any annual values included in the model were treated as exogenous. The statistics of fit for this historical simulation are presented below in Table 5.

In general, the model does a reasonable job of predicting the values of the endogenous variables. With respect to the farm price and meat production variables, identified earlier as the key variables for this model, the

TABLE 5. Statistics of Fit

Endogenous Variables	RMS Per Cent Error
Farm Prices:	
Fed Beef	0.0997749
Nonfed Beef	0.1126740
Pork	0.1851590
Poultry	0.1250710
Feeder Steers	0.1177420
Per Capita Demands:	
Fed Beef	0.0550864
Nonfed Beef	0.0755882
Pork	0.0640157
Poultry	0.0329750
Production:	
Fed Beef	0.0544992
Nonfed Beef	0.0946046
Pork	0.0639139
Poultry	0.0314975
Inventories:	
Sows Farrowing	0.0836010
Cattle Placed on Feed	0.0509025

performance of the model was considered quite satisfactory. The demands for the various meats also had relatively low RMS simulation errors as did the variable representing the number of cattle placed on feed (IP).

Impact and Total Multipliers

One way in which an econometric model can be used is to determine the effect or impact of changes in exogenous variables on the endogenous variables. An example of such use of an econometric model to analyze the effects of changes in policy instruments is found in a later section of this chapter. There, the immediate and long-term effects of the change in corn support price proposed by the administration on the prices received by livestock producers and paid for meat products by consumers are presented.

In general, for linear models, one can obtain the impact multipliers directly from the reduced form equations of the model, that is, the reduced form coefficient of each predetermined variable is that variable's impact multiplier. For example, using matrix terminology,

$$AY(t) + CX(t) = 0 \quad \text{and } U \text{ represents } (5.1)$$

where A is an nxn matrix of coefficients of the endogenous variables, Y is an nx1 vector of endogenous variables, C is an nxm matrix of coefficients of the predetermined variables, and X is an mx1 vector of predetermined variables. The reduced form is given by

$$Y(t) = -A^{-1}CX(t) = D_1X(t) \quad (5.2)$$

where $D_1 = -A^{-1}C$

$D_{ij} = dy_i/dx_j$ which is the nxm matrix of the reduced form multipliers.

The impact multiplier measures the current-period or initial change in the endogenous variable brought about by a change in the exogenous variable.

Reduced Form and Dynamic Multiplier Derivation

In this section, an explanation of the derivation of the reduced form equation system and impact and total multipliers is presented using the matrix algebra approach.

Mathematical Representation Mathematically, the concept of impact multipliers for a linear or linearized system of equations is given by the following relation.

$$AY(t) + BY(t-1) + CX(t) = U(t) \quad (5.3)$$

Where A and B are nxn matrices, C is an nxm matrix, Y is an nx1 vector of endogenous variables, X is an mx1

vector of exogenous variables, and U represents the disturbance terms in the system.

The final form, which expresses each endogenous variable as a function of the predetermined variables in the system (the exogenous and lagged endogenous variables), is given by (5.4) below.

$$Y(t) = D_1 Y(t-1) + D_2 X(t) + V(t) \quad (5.4)$$

where $D_1 = -A^{-1}B$

$$D_2 = -A^{-1}C$$

$$V(t) = -A^{-1}U(t).$$

The impact multiplier is defined as the impact of a unit change in the j^{th} exogenous variable in time period (t) on the i^{th} endogenous variable for the same time period. The reduced form coefficient matrix, D_2 , is also the short-run or impact multiplier for the system given in (5.4) above. That is

$$dY(t)/dX(t) = D_2 = |d_{2ij}|.$$

The long-run or total multiplier is defined as the impact of a unit change in the j^{th} exogenous variable, sustained at this level for successive periods, on the i^{th} endogenous variable. To derive the long-term multipliers, one must examine the time path of the system. Ignoring the error terms, $V(t)$, this time path becomes

$$Y(t+1) = D_1 Y(t) + D_2 X(t+1) \quad (5.5)$$

$$Y(t+2) = D_1 Y(t) + D_2 X(t+2)$$

Substituting $Y(t)$ from (5.4) above gives

$$Y(t+2) = D_1^2 Y(t) + D_2 X(t+2) + D_1 D_2 X(t+1)$$

Intended multipliers for the k^{th} period impacts are given by

$$Y(t+k) = D_1^k Y(t) + D_2 X(t+k) \quad (5.6)$$

$$+ D_1 D_2 X(t+k-1) + \dots \quad (5.10)$$

$$+ D_1^{k-1} D_2 X(t+1).$$

Stability in the dynamic system occurs if

D_1^k approaches zero as k approaches infinity. From

the implied condition of the long-run multipliers, the exogenous variables remain constant over time such that

Another way in which the total effect of the

exogenous change can be presented is given below.

$$Q = D_2 + (1 - D_1 + D_1^2 + \dots)(D_1 D_2)$$

$$= D_2 + (1 - D_1)^{-1} (D_1 D_2)$$

$$= (1 - D_1)^{-1} ((1 - D_1) D_2 + D_1 D_2)$$

$$= (1 - D_1)^{-1} D_2$$

where Q represents the total effect which is found by

summing all the interim multipliers for the system.

$$X(t+1) = X(t+2) = \dots = X(t+k) = X^*$$

this implies that

$$Y(t+k) = (I + D_1 + D_1^2 + \dots + D_1^{k-1})D_2X^* \quad (5.7)$$

Interim multipliers for the k^{th} period impacts are given by

$$dY/dX^* = D_2 \quad \text{for } k = 1 \quad (5.8)$$

$$dY/dX^* = (I + D_1)D_2 \quad \text{for } k = 2 \quad (5.9)$$

$$dY/dX^* = (I + D_1 + D_1^2)D_2 \quad \text{for } k = 3 \quad (5.10)$$

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The long-run or total multiplier is given by

$$dY(t+k)/dX^* = (I - D_1)^{-1}D_2. \quad (5.11)$$

Another way in which the total effect of the exogenous change can be presented is given below.

$$\begin{aligned} G &= D_2 + (I + D_1 + D_1^2 + \dots)(D_1D_2) \\ &= D_2 + (I - D_1)^{-1}(D_1D_2) \\ &= (I - D_1)^{-1}((I - D_1)D_2 + D_1D_2) \\ &= (I - D_1)^{-1}D_2 \end{aligned}$$

where G represents the total effect which is found by summing all the interim multipliers for the system.

Effects of Impact and Total Multipliers

In the next few sections, the effects of the impact multipliers and the total or long-term multipliers for nonfed beef imports, pork imports, and income will be presented and analyzed using data for the third quarter of 1971, which roughly corresponds to the midpoint of the observations.

Effects of Changes in Imports of Beef

It is assumed that the majority of beef imported into the United States is of the nonfed variety. In Table 6, the short-term and long-run effects of a one-unit change (one unit = one million pounds) in imports of beef on some of the more important endogenous variables is presented.

The effect of increased beef imports is greatest in the domestic beef industry. In the fed beef sector, the result would be an immediate decrease in production. The producer and retail prices of fed beef and producer price of feeder steers also would shift downward. Domestic nonfed beef production and producer prices would decrease due to the increase in total nonfed beef supply.

In the short run, pork and poultry production are unaffected by increases in imports of beef. The long-run

TABLE 6. Beef Import Multipliers

Variable	Impact Multiplier	Total Multiplier
Farm Prices:		
Fed Beef	- 0.010904000	- 0.02157870
Nonfed Beef	- 0.010629600	- 0.03478470
Pork	- 0.008904000	- 0.04952010
Poultry	- 0.008773090	- 0.00374982
Feeder Steers	- 0.017319700	- 0.05435500
Retail Prices:		
Fed Beef	- 0.026294700	- 0.05010000
Nonfed Beef	- 0.037340900	- 0.11599600
Pork	- 0.018027600	- 0.09262000
Poultry	- 0.014439800	- 0.00610000
Production:		
Fed Beef	- 0.089160300	- 1.10337000
Nonfed Beef	- 0.142973000	0.33664700
Pork	0	0.50516200
Poultry	0	- 1.21604000

effect would be seen in increased pork production and a decrease in the amount of poultry produced.

Effect of Changes in Pork Imports

As is shown in Table 7, increasing pork imports would result in an immediate decrease in producer prices of all four meat groups. Similar results also would occur with regard to retail prices for fed and nonfed beef, pork, and poultry.

TABLE 7. Pork Imports Multipliers

Variable	Impact Multiplier	Total Multiplier
Farm Prices:		
Fed Beef	- 0.09915920	- 0.02553040
Nonfed Beef	- 0.00920773	- 0.04106420
Pork	- 0.02877110	- 0.08561140
Poultry	- 0.00982997	- 0.00480222
Feeder Steers	- 0.01508040	- 0.06417670
Retail Prices:		
Fed Beef	- 0.02390800	- 0.05847600
Nonfed Beef	- 0.03234070	- 0.13504800
Pork	- 0.05755560	- 0.16138900
Poultry	- 0.01615390	- 0.00774626
Production:		
Fed Beef	- 0.08108120	- 1.30542000
Nonfed Beef	- 0.12207300	0.39986600
Pork	0	0.87333500
Poultry	0	- 1.55733000

From the magnitudes of the multipliers in the table, it is obvious that, in the long run, feeder steer and hog prices would be affected the most by increased pork imports. Some of the other long-term effects of increasing the amount of pork imported into the United States would be increased production of pork and nonfed beef and downward shifts of about equal magnitudes in fed beef and poultry production.

Effect of Changes in Income

As is shown in Table 8, a change in income will have varying effects on the endogenous variables in this study. For example, the immediate impact of an increase in income on producer prices for nonfed beef, hogs, and feeder steers would be negative. Poultry and fed beef producer prices would increase in the short-run as a result of increased income.

TABLE 8. Income Multipliers

Variable	Impact Multiplier	Total Multiplier
Farm Prices:		
Fed Beef	1.2898200	2.108840
Nonfed Beef	- 0.3268230	1.788330
Pork	- 0.4867040	2.806220
Poultry	0.9021070	0.339517
Feeder Steers	- 0.2649110	2.959040
Retail Prices:		
Fed Beef	3.0186000	4.798900
Nonfed Beef	- 1.1448000	5.586000
Pork	- 0.9735000	4.935000
Poultry	1.4399000	0.540690
Production:		
Fed Beef	10.5467000	107.830000
Nonfed Beef	- 10.5269000	-60.805400
Pork	0	-28.626700
Poultry	0	110.103000

The long-run effect of increased income on producer prices is to increase all of them. Hog and feeder steer prices exhibit the largest increases of approximately the same magnitude while poultry prices increase by the smallest absolute amount.

The long-term effect on production of fed beef and poultry is positive. Nonfed beef was found to be an inferior good by several of the previous researchers. Therefore, the negative income-production relationship was not totally unexpected. The negative effect of increased income on pork production was, however, not what one would expect. One possible explanation is that the increased profitability of cattle production and feeding operations could eventually result in a reallocation of resources away from hog production to the more attractive fed beef industry.

Policy Analysis

One way in which an econometric model can be used is to analyze the possible effects of policy decisions before those decisions are implemented. While there are many possible scenarios that could be considered for such analysis, one very timely situation involves the current

administration's 1985 Farm Bill. One section of this proposed bill would lower loan rates for wheat and other feed grains, at the rate of no more than five per cent per year, to approximately 75 per cent of a three-year moving average of domestic market price. The stated objective of this proposed change is to make United States farm products competitive in world markets by curtailing or modifying such programs that, according to the administration, have served to support commodity prices at artificially high levels, thus allowing foreign competitors to undersell United States producers.

For this study, the effects of lowering the corn loan rate to 75 per cent of the average domestic price on several of the key endogenous variables for the third quarter of 1971, selected as a midpoint observation, will be examined and discussed.

Effects of Changes in Corn Price Supports

In the following sections, the short-run, interim, and long-run effects of a 25 per cent reduction in the support price for corn on the farm price of fed beef, PF1, are presented along with the long-term effects on several of the other key endogenous variables. These other variables include producer prices for nonfed beef (PF2), pork (PF3),

poultry (PF4), and feeder steers (PF5); retail prices (PRi); and meat production (XSi).

Although the intent of the administration, as expressed in the the proposed 1985 Farm Bill, is to lower the corn support price gradually, a "one-shot", one-period analysis was selected for use in this study in order to present a worst-possible-case scenario.

Effects on Producer Price of Fed Beef

In Table 9, the price response of the farm or producer price of fed beef to the proposed 25 per cent reduction in corn support price is presented for 16 periods after the change occurs. Inclusion of the interim effects (periods 1 through 15) allows a tracing of the adjustments being made in the price of fed beef as a result of the initial change in the exogenous corn price variable. The total effect is the sum of all the adjustments.

As is shown in Table 9, the price of fed beef would immediately rise by \$0.62 per hundredweight. The price response is greatest in absolute terms for the second and fourth quarters after the change in corn support price, gradually decreasing to about \$0.01 in the fifteenth and sixteenth quarters. The sign changes for the periods representing the eleventh through thirteenth quarters serve

TABLE 9. Effect of Reduction in Corn Support Price on PF1

Period	Price Response of PF1 (\$)
0	0.624
1	0.797
2	0.239
3	0.785
4	0.501
5	0.350
6	0.254
7	0.129
8	0.056
9	0.017
10	- 0.004
11	- 0.008
12	- 0.004
13	0.003
14	0.011
15	0.011
Total	3.90

to indicate the complexity of the adjustment process in producer price of fed beef resulting from the change in the exogenously determined corn support price. The magnitude of the cumulative or total price effect appears to indicate that a reduction in the exogenous variable would result in increased profitability for cattle feeding operations.

Some Long-term Effects of a Change in Corn Support Price

In Table 10, the long-run or cumulative effects of lowering corn price support by 25 per cent on several

endogenous variables are presented.

TABLE 10. Long-Run Effect of Reduction in Corn Support Price

Variable	Response	Units
Farm Prices:		
Nonfed Beef	8.63	(\$)
Pork	13.07	(\$)
Poultry	- 0.29	(\$)
Feeder Steers	13.53	(\$)
Retail Prices:		
Fed Beef	8.63	(\$)
Nonfed Beef	31.71	(\$)
Pork	27.47	(\$)
Poultry	- 0.51	(\$)
Meat Production:		
Fed Beef	454.52	mil. lbs.
Nonfed Beef	-282.49	mil. lbs.
Pork	-107.70	mil. lbs.
Poultry	364.00	mil. lbs.

As shown in Table 10, the cumulative effect of the reduction in the corn support price on producer prices is that the prices of nonfed beef (PF2), hogs (PF3), and feeder steers (PF5) would all increase by varying amounts. The producer price of poultry (PF4) would decrease by a very

modest \$ 0.29 per hundredweight. The increased profitability of cattle feeding would be reflected by an increase in production of fed beef (XS1). The negative long-run response in production of nonfed beef (XS2) and pork (XS3) could be explained by a substitution by consumers of the relatively more preferred fed beef for these two meat products.

along with a brief evaluation of the perceived strengths and weaknesses of the model. In the third section, some suggestions for further research will be made with particular emphasis placed on those things which could potentially enhance the usefulness of the model.

Summary

The main or overall objective of this study was the development of a quarterly econometric model of the United States livestock sector. The complete specification of the economic model and the estimated results of the quarterly econometric model were presented in Chapters 3 and 4. The structural model contained 29 equations of which 17 explain behavioral relationships. In addition to farm and retail prices, 13 of the more important endogenous variables determined by the model were fed and nonfed beef cattle, hogs, and broilers production and inventory. Demand for

SUMMARY, CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

In this chapter, the first section will contain a brief summary of the objectives of this study together with some comments as to how effectively they were achieved. In the second section some conclusions drawn from the results of the model developed for this study will be presented, along with a brief evaluation of the perceived strengths and weaknesses of the model. In the third section, some suggestions for further research will be made with particular emphasis placed on those things which could potentially enhance the usefulness of the model.

Summary

The main or overall objective of this study was the development of a quarterly econometric model of the United States livestock sector. The complete specification of the economic model and the estimated results of the quarterly econometric model were presented in Chapters 3 and 4. The structural model contained 29 equations of which 17 explain behavioral relationships. In addition to farm and retail prices, some of the more important endogenous variables determined by the model were fed and nonfed beef cattle, hogs, and broilers production and inventory. Demands for

the four meat categories were estimated on a per capita basis. The model was estimated over the years 1960-1981. The equations in the model were estimated either by ordinary least squares (OLS) or, in the case of equations with jointly endogenous variables, by two-stage least squares (2SLS). The own-price and income elasticities of demand were estimated for the four meat categories. The results obtained were similar to those reported by other researchers. In terms of model structure, livestock and meat groups included, estimation techniques, and general results, this model is most similar to that of Arzac and Wilkinson (1). The two major differences between the two models were that in this model a per capita basis was used for the demand equations while theirs were estimated on a total basis and the inclusion in Arzac and Wilkinson's model of a block of equations for the feed grains sector.

A second objective involved simulation of the model over the period of the study in order to evaluate the ability of the model to accurately predict values for the endogenous variables. Validation by historical simulation over the period 1960 quarter 2 through 1980 quarter 3 demonstrated the model's ability to track well. The simulation results as measured by the root mean square

simulation error compared quite favorably with those reported by other researchers.

A third objective involved use of the model in analysis of effects of changes in policy with regard to the administration's proposed farm program. Specifically, it was desired to ascertain what effects changes in corn support price would have on farm or producer prices for cattle, hogs, and poultry. These effects were measured by the impact and total multipliers for corn support price.

The fourth objective was to provide an econometric model of the livestock sector, a needed component for a large composite price forecasting project of which this study is a part.

Conclusions

In general, it is felt that the model developed for this study will provide an effective tool for use in the composite price forecasting project mentioned above. In addition, the model can be used for further policy analysis. The simulation results would indicate that the model explains decisionmaking in the livestock sector adequately, especially in light of the fact that the historical period included the mid-1970 period which was characterized by more than usual price volatility.

For the most part, this study built on the work of previous livestock sector modelers, in particular that of Bain, Freebairn and Rausser, and Arzac and Wilkinson was most important. One conclusion that might be drawn from the similarity of the results obtained from this study with theirs is that all are accurately representing and quantifying the structure of the livestock sector and the behavior of livestock producers.

Suggestions for Further Research

In the next few sections, some suggestions for modifications and/or extensions of this model are presented. They represent areas where lack of time and resources necessitated compromise in terms of what one would have liked to have accomplished.

Fed and Nonfed Beef

The first suggestion involves the division or disaggregation of beef into fed and nonfed components rather than use of a total beef category. While it is apparent that there are distinct differences in the production processes which result in fed beef (table cuts) and nonfed beef (ground beef/hamburger), there is a problem with the data used to estimate these two components. There is much

manipulation of the data required in order to derive estimates of fed beef (see Methodology section in Appendix). Another complicating factor is the discontinuance of some of the USDA series necessary to estimate fed and nonfed beef production. This has caused the data base to become even weaker. For these reasons, it is suggested that use of total beef would be preferable to use of estimates subjected to so much "ad hockery."

Stocks of Meat

A second suggestion for extension of this model involves the demand equations for the various meat groups. The identity for total demand, XDi , is of the form

$$XDi + EXi = XSi + IMXi$$

where EXi = meat exports

$IMXi$ = meat imports

XSi = domestic production of meat.

Thus, stock changes are included in the demand concept. This could account for some problems encountered in estimating the demand equations early in the estimation process. One way to circumvent this problem is to expand the model to include separate relations for stocks.

Autocorrelation Problem

The presence of autocorrelated errors or disturbance terms was noted during the estimation process. While the estimators are still unbiased, they are not the best or most efficient. In this study, there was no correction done for this problem due to the degree of difficulty encountered in the correction process and the expense involved. It would be desirable for such correction to be done in the future if time and resources permit.

Other Suggested Changes

One other addition that could be made is to include the importation of live animals in the model. For example, feeder calves are imported from Mexico and Canada and hogs have been imported from Canada for the past several years. While the size of these imports relative to domestic production of these animals may not be very large, inclusion of these data would result in a more complete specification of the supplies of feeder cattle and hogs.

In the past, corn prices were considered to be exogenous in many livestock models. The major reason given for this was the belief that government involvement in the form of support and target prices resulted in prices that were not really determined by the free play of market

forces. If the proposed lowering of support rates and general divestiture by the federal government does come about, it might then be appropriate to investigate the development of a relation or block of equations to explain corn prices and production.

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APPENDIX 1

In the first part of this appendix, the computational procedures or methods for estimating some of the endogenous variables will be presented. The second part contains definitions of each of the endogenous and exogenous variables as well as a listing of sources of the base data used to estimate the econometric model.

Methods of Estimation of Some Endogenous Variables

The following are explanations of the methods used to estimate some of the variables included in the model.

Fed and Nonfed Beef Production

In order to estimate fed beef production for 1975 quarter 1 through 1981 quarter 4, the following procedure was used.

The number of steers and heifers slaughtered monthly under federal inspection and average dressed weight for steers and heifers were taken from Tables 87 and 115, respectively, of the Livestock and Meat Statistics, 1983, and used in a regression equation to predict the carcass weight of fed beef. The equation was of the following form.

Average Carcass = $B0 + B1 (S/S+H)*SWT + B2 (H/S+H)*HWT$

Weight + $B3*Q1 + B4*Q2 + B5*Q3$

Where S = number of federally inspected steers slaughtered

H = number of federally inspected heifers slaughtered

SWT = average dressed weight of steers slaughtered under federal inspection

HWT = average dressed weight of heifers slaughtered under federal inspection

The number of fed cattle marketed in each quarter was multiplied by the average carcass weight for fed cattle as derived above to obtain an estimate of quarterly fed beef production. The number of fed cattle marketed was found in various issues of the Livestock and Meat Outlook and Situation Reports.

Quarterly nonfed beef production was estimated as the residual or difference between total beef production (from Livestock and Meat Outlook and Situation Reports) and estimated fed beef production.

Quarterly Broiler Production

The method used to estimate quarterly production of broilers for the years 1960 through 1964 for the United States is given below.

First, monthly and annual data were collected for liveweight federally inspected slaughter of broilers from USDA Situation Reports and other special annual publications. Total annual broiler production on a liveweight basis was taken from Agricultural Statistics for various years. Broiler production was then converted from a liveweight to a ready-to-cook (RTC) basis using the same factor that the USDA has used for this conversion since 1958 (72 percent). Total monthly broiler production was estimated by multiplying monthly federally inspected slaughter by the ratio of annual RTC production to annual federally inspected RTC slaughter. This method conforms to that used by the USDA to estimate monthly production.

Monthly estimated broiler production on a ready-to-cook basis was summed for the appropriate months of each quarter. The result was a quarterly estimate of broiler production compatible with the later years of the time series.

Dressing Percentage for Hogs

The first step in estimation of a dressing percentage for hogs was to estimate monthly hog slaughter on a liveweight basis. This was done by multiplying the average liveweight of hogs slaughtered by the number of hogs

slaughtered. Quarterly estimates were computed by summing the appropriate monthly totals. Next, monthly commercial pork production was summed to provide quarterly totals. The dressing percentage was then calculated as a ratio of the quarterly commercial pork production to quarterly estimated liveweight hog slaughter.

Base Data Information

Table 11 contains the base data information for the econometric model developed for this study.

TABLE 11. Base Data: Source, Definition, and Listing

TABLE 11 (CONTINUED)

Endogenous Variables:	Description and Source:
IP	Cattle and calves on feed, 23 states (28, 29, 30, 31, 32).
IP4	Prior placement of cattle and calves on feed. Sum of placements lagged 1, 2, and 3 quarters and current placements divided by 4.
KB	Inventory of beef cows.
KC	Net calf crop; calf births minus calf deaths (42).
Mi	Retail producer price spread (42, 44, 45).
PF1	Farm or producer price of choice slaughter steers, Omaha.
PF2	Farm price of utility cows, Omaha.
PF3	Farm price of pork, average price of barrows and gilts and sows in 7 markets (42).
PF4	Farm price of broilers, monthly average on a ready-to-cook basis (35, 44, 45).
PF5	Farm price of choice feeder steers, Kansas City (42).
PR1	Average retail price of choice grade beef
PR2	Average retail price of ground beef
PR3	Average retail price of pork (43).
PR4	Average retail price of frying chicken (35, 44, 45).
SC	Number of calves slaughtered (42).
SF	Number of sows farrowing (37, 38, 39, 40, 41).

TABLE 11 (continued)

XD1PC	Per capita demand for fed beef.
XD2PC	Per capita demand for nonfed beef. See Bain (1) for 1960-74; for 1975-81 see methods section in this Appendix.
XD3PC	Per capita demand for pork (42, 43).
XD4PC	Per capita demand for broilers (45).
XS1	Fed beef production.
XS2	Nonfed beef production. See Bain (1) for 1960-1974; for 1975-81 see methods section in this Appendix.
XS3	Pork production. (43).
XS4	Broiler production. See methods section in this Appendix.
Zi	Retail prices (PRi) deflated by CPI.

Exogenous
Variables:

Description and Source:

B1	Choice beef by-product allowance
B3	Pork by-product allowance (42, 43).
CPI	Consumer price index (7, 46).
DP	Dressing percentage for hogs. See methods section in this Appendix.
EX1	Exports of beef
EX3	Exports of pork (43).
EX4	Exports of poultry (45).

TABLE 11 (continued)

ID	Dairy herd replacements (42).
IMX2	Imports of beef
IMX3	Imports of pork (43).
KD	Inventory of dairy cows (42).
LP	Index of productivity in poultry production (33).
PG1	Corn price: average received by farmers per bushel (36).
POP	U.S. civilian population (46).
PSPS	Pigs saved per litter (37, 38, 39, 40, 41).
W	Average hourly wage rate in meatpacking
W2	Average hourly wage rate in poultry dressing (47).
Y	Current disposable income. (46).
YZ	Real disposable income (Y/CPI).
